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AIR POLLUTION ASPECTS OF AEROALLERGENS (POLLENS)

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Bethesda, Maryland

September 1969

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AIR POLLUTION ASPECTS
OF
AEROALLERGENS (POLLENS)

Prepared for the
National Air Pollution Control Administration
Consumer Protection & Environmental Health Services
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FOREWORD

As the concern for air quality grows, so does the concern over the less ubiquitous but potentially harmful contaminants that are in our atmosphere. Thirty such pollutants have been identified, and available information has been summarized in a series of reports describing their sources, distribution, effects, and control technology for their abatement.

A total of 27 reports have been prepared covering the 30 pollutants. These reports were developed under contract for the National Air Pollution Control Administration (NAPCA) by Litton Systems, Inc. The complete listing is as follows:

Aeroallergens (pollens)
Aldehydes (includes acrolein and formaldehyde)
Ammonia
Arsenic and Its Compounds
Asbestos
Barium and Its Compounds
Beryllium and Its Compounds
Biological Aerosols (microorganisms)
Boron and Its Compounds
Cadmium and Its Compounds
Chlorine Gas
Chromium and Its Compounds (includes chromic acid)
Ethylene
Hydrochloric Acid
Hydrogen Sulfide
Iron and Its Compounds
Manganese and Its Compounds
Mercury and Its Compounds
Nickel and Its Compounds
Odorous Compounds
Organic Carcinogens
Pesticides
Phosphorus and Its Compounds
Radioactive Substances
Selenium and Its Compounds
Vanadium and Its Compounds
Zinc and Its Compounds

These reports represent current state-of-the-art literature reviews supplemented by discussions with selected knowledgeable individuals both within and outside the Federal Government. They do not however presume to be a synthesis of available information but rather a summary without an attempt to interpret or reconcile conflicting data. The reports are necessarily limited in their discussion of health effects for some pollutants to descriptions of occupational health exposures and animal laboratory studies since only a few epidemiologic studies were available.

Initially these reports were generally intended as internal documents within NAPCA to provide a basis for sound decision-making on program guidance for future research activities and to allow ranking of future activities relating to the development of criteria and control technology documents. However, it is apparent that these reports may also be of significant value to many others in air pollution control, such as State or local air pollution control officials, as a library of information on which to base informed decisions on pollutants to be controlled in their geographic areas. Additionally, these reports may stimulate scientific investigators to pursue research in needed areas. They also provide for the interested citizen readily available information about a given pollutant. Therefore, they are being given wide distribution with the assumption that they will be used with full knowledge of their value and limitations.

This series of reports was compiled and prepared by the Litton personnel listed below:

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ABSTRACT

Aeroallergens (pollens) are airborne materials which elicit a hypersensitivity response in susceptible individuals. The two major responses exhibited are allergic rhinitis and bronchial asthma. The importance of aeroallergens as air pollutants is shown by the statistic that an estimated 10 to 15 million people suffer from seasonal allergic rhinitis (hay fever) in the United States. The pollens of wind-pollinated plants are the most important of the aeroallergens, and ragweed pollen is commonly found in this group. Ragweed pollen is the cause of more than 90 percent of pollinosis in this country. Other aeroallergens include molds, house dust, danders, and a miscellaneous group of insecticides, cosmetics, paints, and vegetable fibers. There is evidence to indicate that the aeroallergens and other air pollutants can act synergistically in affecting human health.

Most of the aeroallergen investigations have been concerned with ragweed. The plant is found primarily in the North Central and Northeastern parts of the United States, but it has spread to some degree to the remaining portions of the country. Ragweed grows best in soil which has been disturbed, and therefore is found in abundance both in farmlands and in urban areas. Pollen counts are taken daily in many local areas throughout the country. These counts are

used as guidelines for anticipating and understanding the incidence of pollinosis in a given area rather than as standards.

Local programs of ragweed eradication generally have met with little success in controlling pollen concentrations. The pollen can be windborne for many miles, and therefore pollen entering a city from the outside usually is sufficient to cause pollinosis in the susceptible population. An adequate program for control would perhaps require an approach on a regional rather than a local basis. There are no adequate estimates of cost values for illnesses caused by aeroallergens, nor are there estimates for the cost of abatement on the scale that would be required for adequate control.

The gravity slide method has been accepted as the standard procedure for pollen sampling by the Pollen Survey Committee of the American Academy of Allergy. However, because of inherent limitations in the procedure, other methods have been devised and are used for special sampling situations.

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1. INTRODUCTION

Aeroallergens (pollens) are airborne materials that elicit a hypersensitivity or allergic response in susceptible individuals. The most common aeroallergens are the pollens of wind-pollinated plants--especially ragweed pollen, which is the main cause of hay fever. Not all individuals are allergic or susceptible, but those who are become sensitized by initial exposure (s) to the allergen (e.g., pollen) and respond with acute allergic symptoms on subsequent challenging exposures. In addition to the pollens, aeroallergens include molds, danders, house dust, cosmetics, and others. These will be discussed briefly in this report; the major emphasis will be on the pollens, and especially ragweed pollen.

There is no question of the adverse effects of aeroallergens on human health. It has been estimated that between 10 and 15 million people in the United States are affected by seasonal allergic rhinitis (hay fever). In addition, many individuals exhibit the more severe syndrome of bronchial asthma, and it is believed that 5 to 10 percent of untreated hay fever patients develop the latter illness.

Ragweed pollen, the most common and the most important aeroallergen in North America, is the cause of more than 90 percent of all pollinosis. Although most common in the Northeastern and North Central part of the United States, the plant is found in other regions of the country as well.

Ragweed grows best in soils which have been disturbed by plowing or other means and, therefore is found in abundance along railroad tracks, highways, in new urban subdivisions, and in farmlands. It has been estimated that one-third of the 60 million acres of wheat stubble fields are infested with ragweed. Since more and more soil has been disturbed over the years, both ragweed growth and the number of hay fever sufferers have been increasing. Therefore, if one considers that man's progress is correlated with urbanization and increased breaking of the soil for new roadways, subdivisions, and farms, then the increase of ragweed and hay fever is a problem resulting from this progress.

2. EFFECTS

2.1 Effects on Humans

2.1.1 Natural Effects

The major effects of aeroallergens on human health are allergic rhinitis and bronchial asthma. Acute allergic dermatitis also sometimes occurs.

Allergic rhinitis is characterized by a profuse, clear, watery nasal discharge, sneezing, and itching of the nose, eyes, roof of the mouth, and posterior pharynx. If these symptoms occur during a particular season of the year, the rhinitis is commonly called hay fever or rose fever and is likely to be caused by plant pollen or mold spores. If the symptoms occur randomly or nonseasonally, they may result from such materials as house dust and animal danders, or nonairborne allergens.

Bronchial asthma is a syndrome characterized by recurrent, periodic paroxysms of wheezing that are frequently associated with dyspnea, choking, and coughing due to obstruction of expiratory air flow. The patient is free of symptoms during periods between attacks. Aeroallergens are associated with bronchial asthma.

Some authorities divide bronchial asthma into two groups: extrinsic and intrinsic.[20] Others consider the syndrome too complex and do not attempt any special groupings.[52] Extrinsic bronchial asthma is thought to be an atopic condition (i.e., a state of clinical hypersensitivity associated with a family history of allergy.) It seems to occur primarily in individuals before the age of 45. Skin tests with known allergens are positive, and the individual has had other clinically determined allergies. Infection of the respiratory tract is not a factor in the symptomatology, although it might complicate the condition later. The symptoms are brought on by exposure to pollens, molds, occupational or house dusts, animal danders, foods, etc. Intrinsic bronchial asthma is not associated with any demonstrable evidence of atopy or family history of allergy, and skin tests are negative. It is more common after age 45, and is associated with infection in the upper respiratory tract.

Allergic dermatitis occurs less commonly than rhinitis or asthma. It is characterized by hives, eczema, or conjunctivitis.

The potential aeroallergens present in nature are numerous. The ease with which humans can be sensitized to these materials varies greatly. Approximately 15 percent of the population in this country is sensitized easily to many materials. These sensitivities often appear at an early age and are severe enough to be obvious, producing symptoms of hay fever, asthma, and eczema. Another 25 to 30 percent of the population is progressively less easily sensitized, and their symptoms are subtle. Most of the remaining 55 to 60 percent appear never to become sensitized. The family history for obvious allergy is usually strongly positive in the first group, less so in the second, and absent in the third. However, on the basis of the physiological processes whereby allergies are manifested, individuals of the third group could also become sensitized, given the proper condition.[64]

In addition to the specific syndromes elicited by the aeroallergens, an additional health problem exists in that further complications may appear in time. There is evidence indicating that sensitivity to one allergen predisposes a sensitivity to other allergens. In addition, some hay fever sufferers develop bronchial asthma, which may be complicated by intractable asthma, pulmonary emphysema, bronchitis, and pneumonitis.[55] In a continuing community survey of Tecumseh, Mich., begun in 1957, hay fever and asthma were separately diagnosed in approximately 10 percent of the 9,800 population, and both hay fever and asthma in approximately 2 percent of the population.[10] Of those persons with a history of asthma, the first attack commonly occurred under the age of 5 years; hay fever frequently began at a later age. The analysis also indicated that 5 to 10 percent of persons subject to hay fever will develop asthma if the disease runs unchecked.[11]

Of the common allergens listed in Table 1, Appendix, the most important natural sources of air pollution concerned with inhalant allergy are the wind-pollinated plants (Table 2, Appendix). Their seasonal and geographical occurrence are shown in Table 3, Appendix. Plants of the ragweed family (*Ambrosiaceae*) are the most frequent cause of hay fever in North America; grass pollens seem to cause most of the cases in Europe; and in the Scandinavian countries blue grass (*Poa pratensis*), timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), rye grass (*Lolium*), and rye (*Secale cereale*) are the chief offenders.[84] In addition, trees are an important source of pollen, causing hay fever throughout North America in the early spring of the year.[60] The ubiquitous allergenic saprophytic molds are found both outdoors and indoors. A list of the most common aeroallergenic molds is presented in Table 4, Appendix.

2.1.2 Dose-Effect Relationship

Some efforts have been made to establish a quantitative dose-effect relationship for pollens. Blumstein[8] and Tuft *et al*.[109] dipped a toothpick into pollen and held it under the patient's nose as the patient inhaled vigorously. Using different pollens, they were able with this method to determine to which pollen the patient was sensitive. The disadvantages of this technique were these: (1) quantitation of the pollen dosage (through dilution with talc) was crude;

(2) a clinical episode of hay fever could be produced by one or two inhalations, thus suggesting that the dosages were massive as compared to ordinary environmental exposure; and (3) the administration of hazardous dosages was possible. Although the quantity of pollen constituting an overdose is unknown, there is evidence which suggests that an overdose is not a fixed amount but probably varies from patient to patient, and even varies in the same patient under differing conditions.[16]

Solomon[103] has reported data which suggest that in persons with allergic rhinitis, prior exposure, body position, and breathing patterns may be important modifying factors in nasal responses. He has initiated studies, the results of which have not yet been reported, utilizing a large test chamber in which the temperature, relative humidity, and duration of extraseasonal pollen exposure of test subjects is possible.[104]

Connell[16,17,18] has devised an apparatus for exposing subjects to quantitative dosages more analogous to environmental exposure levels. The apparatus consists of a 22-liter flask in which the pollen is kept in suspension. The patient applies a face mask connected to the flask and inhales through his nose. Sensitive individuals respond with the clinical signs and symptoms of hay fever: itching of the eyes, ears, nose, and throat; nasal discharge; etc. Dosages can be controlled so that the total accumulative nasal exposure (challenge) in an hour is from 100 to 300 pollen grains. It was found that hay fever symptoms were frequently produced by as little as 100 grains in a 1-hour challenge. Nonallergic individuals have showed no response to as much as 50,000 grains in 30 minutes. Connell's studies showed that with daily ragweed pollen challenges, smaller and smaller doses were required each succeeding day to cause the same or greater degree of hay fever. He called this increased sensitivity the "priming effect" and concluded that environmental exposure during the ragweed pollinating season similarly caused priming of the nasal membranes. The priming was reversible, and the time period (days to weeks) for priming was dependent upon the degree of exposure to the pollen. When pollen was administered only to one nostril, unilateral priming and allergic rhinitis occurred only in that nostril, and resistance of the other nostril remained unchanged. In the case of one individual, after 2 weeks of daily priming of one nostril, response was obtained to a total dose of 30 ragweed pollen grains, but the non-primed nostril showed no response to 303 grains. It took additional exposure to pollen (priming and challenge) before the latter nostril also responded. Connell further observed that in subjects sensitive to more than one pollen, priming could be accomplished with one pollen (such as sorrel) and the hay fever symptoms produced by challenge with another pollen (such as ragweed).

2.1.3 Synergistic Responses and Effects of Unknown Substances

Naturally occurring aeroallergens such as pollens have been known and studied for several decades. However, the ability of other air pollutants to cause a potentiating or synergistic response with the natural allergens has become a new area of study in recent years.

Schoettlin and Landau[94] studied 137 asthmatic patients in the Los Angeles area for 98 days (September 3 to December 9, 1956). This period roughly corresponded to the smog season. They studied the number of asthmatic attacks in relationship to air pollution as measured by total atmospheric oxidants, particulates, carbon monoxide, relative humidity and temperature, and plant damage. Low positive correlations were found between chemical measures of air pollution and the number of persons suffering attacks. Low correlations were also noted for temperature, relative humidity, and water vapor pressure. A significantly greater number of persons had attacks on days with oxidant values high enough to cause eye irritation or cause plant damage than on other days. Sterling *et al.*,[106] also in Los Angeles, observed an increase in hospital admission rates for allergic disorders as well as a number of other respiratory syndromes on days of high air pollution (Table 5, Appendix).

Zeidberg et al.[117] reported on an extensive air sampling and medical evaluation study of Nashville, Tenn. They observed a group of 84 patients with bronchial asthma--49 adults and 35 children--for a 10-month period (October 1958 to July 1959). A total of 3,647 asthmatic attacks occurred during 27,440 person-days of observation. An overall attack rate of 0.133 per person-day was reported. In adults, the asthmatic attack rate varied directly with the sulfate level in their residential environment and was three times as high for those living in the high pollution area as for those in the low. This correlation could not be demonstrated with the children.

Following a 2-year epidemiological study of asthma in children in Philadelphia, Girsh et al.[40] concluded that the occurrence of stable weather conditions with stagnant air seemed to correlate with peak incidences of bronchial asthma. They had observed a total of 1,346 patients during the two-year period; the average normal 24-hour incidence of asthma was 2.5 patients (standard deviation of ± <2). The incidence was considered high when five or more patients were seen in 24 hours; and on 70 days of the 676 days, the incidence was 5 to 14 per 24 hours. The incidence of bronchial asthma was three times greater during days of high air pollution, and there was a fourfold increase during days with high barometric pressure. When both air conditions coincided, there was approximately a ninefold increase in bronchial asthma. The authors concluded that the greater incidences were not due to ragweed pollen, but speculated that some unknown pollutant was present which was not being measured.

Booth et al.[9] studied the records of asthma emergency visits for 10 hospitals in seven cities during 1960. For most of the hospitals, noticeable peak months for asthma occurred in the autumn of the year, as shown in Table 6, Appendix. No single cause could be established; the investigators' conclusions were that multiple causes probably had existed.

Greenburg and co-workers have analyzed records of emergency clinic visits for asthma and for other respiratory illnesses in New York City hospitals for a number of years in relationship to air pollution episodes. Although they observed an increase in upper respiratory infections during the November 1953 air pollution incident, there was no associated increase in asthma clinic visits.[46] Continuing their analysis, Greenburg et al.[47,48,49] observed that peak rates of asthma clinic visits occurred in September for the years 1957, 1961, 1962, 1964, and 1965 (Tables 7 and 8, Appendix), but that there was no correlation of the visits with air concentrations of pollens, molds, or other air pollutants. The best correlation seemed to be with the onset of cold weather. They speculated either that the first onset of cold weather was the "triggering" factor, or that the first indoor home heating following the summer months stirred up dormant allergenic dust and mold particulates, or that something was present in the air which was not being measured.

The monthly admissions for asthma and asthmatic bronchitis to the Brisbane Children's Hospital in Australia for three years, July 1955 to June 1958 (Table 9, and Figures 1 and 2, Appendix), showed a minor increase during the spring months and a major wave in autumn and early winter.[23] It was concluded by Derrick _et al_. that the seasonal occurrences of these attacks were not correlated with atmospheric pressure, temperature, humidity, rainfalls, hours of sunshine, or wind velocity or direction. They suspected the cause of the seasonal peaks was an unidentified pollen or pollens.

New Orleans has been a subject of study since 1958 when an outbreak of asthma occurred resulting in approximately 100 cases and 3 deaths. This pattern reoccurred in following years. In earlier reports, asthmatic attacks have been associated with certain local wind conditions.[68] At first, spontaneous underground combustion in abandoned city dumps seemed to be responsible. However, a recent study suggests that there is more than one air pollution source causing an asthmatic-type disease in New Orleans, and that there are probably multiple sources.

Kantor et al.[63] reported on an aerobiological survey conducted concurrently with a study of 56 clinically determined asthmatics who lived for a period of one year in the new Judean desert town of Arad. The pollen and mold concentrations in the air of Arad were about one-third and one-half, respectively, of those observed at the same time of day in the central coastal community of Beilinson, Israel, where the humidity was higher and more vegetation existed. (See Table 10, Appendix). Excellent to moderate clinical responses were observed in 84 percent of the patients during their stay in Arad, followed by relapse on their return home to Beilinson. The speculation was that the mold and pollen concentrations represented a subthreshold level for the patients, which they could tolerate without any adverse effects.

2.1.4 Effects of Vegetable Dusts

The harmful effect of grain dust on health has been recognized for many years. However, there was little interest in the scientific literature concerning this subject until Duke[29] described four cases of bronchial asthma among flour mill workers, who experienced asthmatic attacks on exposure to the dust from the first cleaning of the wheat grain. Other reports have since appeared describing adverse health effects caused by grain dust among workers loading and unloading grain[30,54] and mill workers.[101] Williams _et al_.[116] surveyed 502 country grain elevator agents in Saskatchewan. Of these, 54 percent had a history of one or more asthmatic symptoms, including attacks associated with exposure to grain dust (oats, wheat, barley, and rye), with barley reported as the most responsible. There was some evidence indicating that the allergic response was due to mold spores (_Aspergillus_, _Penicillium_, _Mucor_, and _Rhizopus_) present in the grain.

Industrial plants that handle, process, and mill cereal grains have been suspected of emitting allergenic dust into the surrounding atmosphere. The University of Minnesota campus in Minneapolis is surrounded by such storage and processing plants. Outbreaks of asthma have occurred from time to time among students at the University, and it was considered that these outbreaks were due to some pollutants from the plants.[41] However, although air samples taken in the vicinity revealed pollens (dependent upon seasonal release), fungi, plant hair, and starch grains from the nearby mills, no correlation was observed between their presence and the incidence of asthmatic attacks. Goppers and Paulus[43] collected air samples from a similar grain milling plant area. Two substances (compounds A and B) were extracted from the collected particles that could cause allergic reactions in persons susceptible to bronchial asthma and hay fever. The investigators extracted a number of grains, seeds, plants, and weed pollens in the same manner and were able to isolate one of the two substances (compound A) from each material examined. Their results are presented in Table 11, Appendix.

Allergic reactions to the castor bean and its products are well known to the allergist. Apen _et_ _al_.[7] have reviewed the literature on the health aspects of castor bean dust up to 1967. Castor pomace is the residue that remains after the castor oil has been removed from the beans of the castor plant, _Ricinus_ _communis_. This pomace contains one of the most potent allergens known, which, in a fine, light powder form, is readily carried by the wind from the processing plant and shipping areas into the surrounding community. A number of well-documented outbreaks of illnesses have been traced to this aeroallergen. For example, Ordman[77] reported an outbreak of bronchial asthma in South Africa caused by inhalation of castor bean dust. The highly allergenic dust affected 200 persons in a castor oil processing plant.

The pressed castor bean has been used increasingly in recent years as a fertilizer. Small[100] reported two patients with bronchial asthma and two with hay fever caused by inhalation of castor bean pomace used as a fertilizer. Additional patients showed positive skin test reactions to the castor bean extract. This investigator anticipated that more cases will occur as the use of the pomace as fertilizer increases.

Panzani and Layton[80] recorded 478 cases of castor bean dust allergy in Marseilles and the neighboring countryside during the period 1951 to 1962. Pollinosis caused by the pollen of the castor bean plant also can occur. Lindenbaum[69] observed a patient who had symptoms of hay fever complicated by asthma. The many castor bean plants growing in the vicinity of the patient's home were the source of the pollen. Layton _et al_.[67] concluded that apparently castor pollen and castor pomace share common antigens. Reactions to the pollen are milder than to the pomace, but the pollen can induce sensitivity to the pomace.

2.1.5 Effects of Molds

The allergies discussed thus far are considered to be atopic allergies[13]--that is, usually characterized by hereditary predisposition and high and immediate sensitivity. Desensitization is difficult and usually only partial at best, skin reactions are marked and specific, and considerable amounts of antibody are demonstrable in the serum. However, in nonatopic allergy, the converse is true; i.e., sensitivity is low and delayed, desensitization is usually successful, skin reactions are weak and nonspecific, and few antibodies are demonstrable in the serum. Nonatopic allergy can also be associated with an infection. Authorities differ on the significance of this classification and whether distinction between atopic and nonatopic allergy is quantitative rather than qualitative. However, most agree that the distinction has clinical utility. This section primarily discusses nonatopic allergy.

Watkins-Pitchford[112] reviewed the occurrences of "farmer's lung" in Great Britain, Europe, and the United States. Pulmonary disability among agricultural workers handling moldy hay and composts has been known for generations, and many of the early descriptions of such cases undoubtedly were what is presently called "farmer's lung." Some hours after exposure to the hay, acute attacks begin that are characterized by shortness of breath, fever, and cough generally followed by recovery. If the acute attack has been severe or if exposure is continued, the illness progresses to a severe dyspnea and cough which become progressively worse. It is generally agreed that "farmer's lung" is an inhalant allergic response to Thermopolyspora polyspora growing in the hay.[24] Although the true incidence of the disease can only be conjectural, it has been estimated that approximately 1,000 cases occur annually in Great Britain.

Sakula[92] reported respiratory symptoms resembling those seen in farmer's lung in workers at mushroom-growing farms. The process of composting on these farms favors the growth of fungi, and the inhalation of their spores is responsible for allergic response of certain mushroom workers. Four cases were reported in Sussex, where 50 percent of the mushrooms in England are commercially grown, and 16 cases among immigrant Puerto Ricans working in the Chester County area of Pennsylvania, where 90 percent of the mushrooms consumed in the United States are cultivated. Similar allergic responses occur in "bagassosis," caused by inhalation of the moldy dust of the bagasse fiber (the sugar cane residue left after removal of the sugar). Asthma symptoms have developed in some individuals following exposure to specific wood dusts.[107] Byssinosis, or cotton lung resulting from inhalation of cotton dust, has been included in this group in the past,[24] but some recent studies indicate that it has a reversible chemical component resembling that of metal fume fever and a chronic component.[58]

Itkins and Dennis[59] tested 81 patients for sensitivity to the common fungus Candida albicans. Forty percent gave positive bronchial reactions to inhalation of the fungus. These results are presented in Table 12 (Appendix).

2.2 Effects on Animals

2.2.1 Commercial and Domestic Animals

Commercial and domestic animals generally are not affected by inhalation of aeroallergens.

2.2.2 Experimental Animals

Experimental animals generally are not affected by inhalation of aeroallergens. However, animals are used in allergy studies. Dogs sometimes show spontaneous sensitivity to ragweed pollen.[1,82] Also, researchers at the National Institutes of Health have begun to work with inbred strains of guinea pigs to study the inheritance of allergic tendencies.[53]

2.3 Effects on Plants

The physiological response of allergy cannot occur in plants, and, therefore, no allergic effects of aeroallergens on plants are possible. However, as an anomalous effect, growers of genetically pure seeds for crops and flowers are faced with the problem of airborne cross pollination with undesirable plants.[87] The disease-producing effects of molds, and other microorganisms on plants is discussed in the companion report on Biological Aerosols.

2.4 Effects on Materials

As in the case of plants, aeroallergens do not produce allergic response on materials. The effects of the growth of molds and other microorganisms on materials are discussed in the companion report on Biological Aerosols.

2.5 Environmental Air Standards

Insufficient information exists on which to establish environmental air standards for the aeroallergens. However, a pollen count, from which a pollen index is derived, is determined daily in many local areas and is compared to previously observed indexes in the same area. The comparison is used as an indication of the incidence of pollinosis to be expected in the susceptible population. Generally, although the values vary from locality to locality, an index of 5 to 15 is considered moderate, and at this level acute hay fever symptoms generally last only a few days. An index above 15 is indicative of heavy pollen concentrations, and 25 or more on any given day will usually cause severe symptoms of hay fever in most of the susceptible population.[39] However, individual sensitivities to the pollen vary, and an extremely sensitive individual may suffer intensely with a low index of 10 while another less sensitive individual may show no response to a count of 100. This situation may even reverse itself in another geographical area, where the prevalence of certain pollens may be different.

The pollen index should be considered only as a guideline rather than as a standard.[38] The counts are obtained on rooftops, and the actual exposure value at street level may be greater or less than this. Also, the counts represent integrated values for the 24-hour period and do not reveal surges of high concentrations which exist for only short periods of time. In addition, small clouds of pollen could occur in certain areas due to local point sources or micrometeorological conditions (i.e., local air calms, turbulences, etc.) and yet not be reflected in the count obtained short distances away. Shapiro and Rooks,[96] in 1951, placed pollen samplers near known stands of ragweed in residential areas of Iowa City. They noted higher values and marked variation of the pollen counts as compared to the counts obtained with the standard procedure of a central sampler on a rooftop.

Regardless of their limitations as a standard, the pollen counts do serve a useful purpose. The more data of this type which are accumulated and analyzed with related meteorological, medical, and control data, the better will be the total understanding of the problem. In addition, the pollen counts aid both the practitioner and the patient. The symptoms of pollinosis can be better diagnosed and understood when there is reported evidence that a certain pollen is prevalent in a given area. After a period of time some individuals may even be able to anticipate an attack of pollinosis on the basis of the daily pollen count and take some precautionary steps, such as avoiding areas high in vegetation and taking medication before the onset of symptoms.

3. SOURCES

3.1 Natural Occurrence

The aeroallergens encompass a wide variety of materials, as shown in Table 1 (Appendix), but the pollens are the most important member of this group. The plants which produce allergenic pollens are widely distributed geographically, and their distribution and seasonal growth characteristics in part determine their importance as aeroallergens. The most prevalent pollen-producing plants have been listed in Table 2 (Appendix), and the most important pollens of each State and their seasonal occurrence are presented in Table 3 (Appendix).

Ragweed has been found in all 50 States; it produces large quantities of pollen, and the pollen grains are especially adapted for aerial dissemination by virtue of their size (20 μ), shape, and density.[60] In addition, because of its allergenic property for a large percent of the population, it has been the most studied.

Approximately 40 species of ragweed are known at the present time, the majority of which occur in North America.[83] Ragweed is most prevalent in the North Central and Northeastern States followed by the Southern, Great Plains, Intermountain, and Pacific Coast States. The weed has also been introduced into Hawaii.[91] Six species are sufficiently widespread and abundant within the United States to be of importance as pollen sources on the State or national level. These ragweed species characteristically establish themselves quickly in freshly turned soil, and their special ability to grow as weeds enables them to flourish in cultivated grain fields, where they are most abundant today. Pollination is by aerial dissemination. Because pollination by wind is very inefficient, many thousands of pollen grains must be liberated and disseminated for effective pollination.

Ragweed tends to be crowded out by other vegetation if the soil is not disturbed. Therefore, the plowing of fields, especially cereal grain fields, is responsible for the growth of a major portion of the ragweed in many areas of the country. The ragweed seedlings develop during the ripening stage of the cereal grain and grow rapidly in the stubble after the grain has been harvested in late summer. An estimated one-third of the 60 million acres of wheat stubble is infested with ragweed.[39] In fields of winter wheat, oats, and barley, with no cover crop, about 172,000 ragweed plants per acre have been observed, which is more than 300 times the plant density in pastures.[55] Ragweed is found also in urban areas where soil has been disturbed. For example, in a new subdivision where the soil had been overturned but untouched during the spring and summer, ragweed concentration amounted to 56,500 plants per acre.[55] Along railroads, one count gave 13,000 plants per acre.[55]

Gorlin[44] has estimated that an acre of giant ragweed may produce as much as 50 pounds of pollen during a single season. A ragweed survey was conducted within parts of the Ann Arbor and Superior Townships of Washtenau County, Mich. Land along selected roads and highways was classified by land use, and the density of ragweed was then determined. The results of the survey showed that the general pattern of ragweed distribution prevailed: high density in croplands and low density in marshes and woodlands, as shown in Table 13, Appendix.

The fungi (molds and yeasts) are an important group of aeroallergens; the most common ones are listed in Table 3, Appendix. These microorganisms are ubiquitous and saprophytic in nature. Their usual habitats are soil and dust, and they become airborne by means of local air disturbances. Their concentration in the air is dependent upon the magnitude of the source, their death rate in the air, humidity, temperature, and other factors. The largest percent of the airborne fungi are found in the air up to 5,000 feet, and their number decreases rapidly above that level. However, viable mold spores have been recovered up to 90,000 feet.[12]

Danders, which include feathers of fowl and hair of animals (including humans), are found in the air close to their source point. Their concentration in the air is limited, and they are allergenic to humans when the source is in close proximity to the susceptible individuals.

House dust consists of the small particulate organic materials (fragments of animal hair, wool, cotton linters, kapok, feathers, pollen which has seeped in from outdoors, etc.) found in the home. Molds are also frequently found in the home--especially in old, damp dwellings (e.g., basements) --and can be included in house dust. The house dust which is of concern in this connection does not include sand, soil, and powdered rock, which are not allergenic.

Voorhorst _et al_.[110] concluded from their studies that the mite _Dermatophagoides pteronysissimus_ was the allergenic agent in house dust. They were able to isolate the mite from such dust, and skin reactions to extracts of this mite in sensitive individuals were both quantitatively and qualitatively indistinguishable from those obtained with house dust. In addition, the mite has a worldwide distribution, as well as seasonal variation of occurrence similar to the frequency of house dust allergenicity (peak in the autumn).

Although a nonspecific house dust extract is available for skin testing, some clinicians believe that house dust is specific for each home. Because it is found in every indoor environment, house dust is probably the most common aeroallergen after pollens.[52] Jaggi and Viswanathan[61] skin-tested patients with seasonal and perennial rhinitis and asthma with extracts of pollen, house dust, and fungi. Of the 462 patients tested, 61.9 percent reacted positively to house dust. Of these positive subjects (286), 17.5 percent were positive to house dust alone, and the rest were positive to one or more of the other allergens beside house dust.

The miscellaneous aeroallergens--which include vegetable fibers and dust, cosmetics, paints, and varnishes --are limited in the air and affect susceptible individuals only when in close proximity to the source. They constitute a minor problem in terms of the total number of people affected.

3.2 Production Sources

The occurrence of certain aeroallergens in the air has been due to production sources. A survey of country grain elevator agents in Saskatchewan showed a greater than 50 percent prevalence of asthmatic and related symptoms in these individuals.[116] Grain dusts produced in flour-milling plants similarly have been the cause of asthmatic and other symptoms in mill workers[29,101] and workers loading and unloading grain.[30,54] There has been some evidence that flour mills can emit the allergenic dust into the surrounding atmosphere. Goppers and Paulus[43] in 1967 were able to isolate both from the air near a flour mill and from grains an unidentified compound which could cause allergic reactions in pollinosis in this country, has been studied the most extensively. Table 15, Appendix, lists a number of pollens and dispersal data.

It has been observed that emission of pollen from ragweed plants is not continuous but is dependent upon the time of day, temperature, and humidity.[75] Pollen release from the ragweed flower is accomplished in the several hours after sunrise, as shown in Figures 3, 4, and 8, Appendix. The release is triggered by the drop in humidity resulting from the warmth of the sun. Usually, only a small percentage of the pollen becomes directly airborne. The great majority of the grains fall on nearby vegetation and soil but may become airborne at a later time.[14] It has been estimated that only approximately 6 percent of the released pollen becomes airborne.[99]

Once airborne, the dispersal of the pollen is dependent upon the horizontal and vertical air movements. Raynor and Ogden[87] in 1965 sampled the air from a cultivated ragweed source 180 feet in diameter and found that if the horizontal air flow is relatively slow (a wind of about 1 m/sec) and the vertical flow is small, the airborne pollen concentration becomes negligible within a short distance. The pollen concentration had dropped to 1/100 of the source concentration at 500 feet from the source. The patterns observed at three different sampling heights of a similar 90-foot-diameter ragweed source are presented in Figure 5, Appendix. Day-to-day concentration patterns varied primarily because of changes in wind direction, speed, and turbulence. A composite of these daily patterns showed the seasonal average concentration around the source, sample at a 5-foot height (Figure 6, Appendix). Although the wind was primarily in one direction, significant amounts of pollen spread in all directions.

Allessio and Rowley[4] in 1956 took a daily pollen count for 7 months at two sites on the University of Massachusetts campus, while looking for and tabulating 42 different pollens plus fern, moss, and fungal spores. Although they could not rule out long-distance dispersal by their results, the presence of all materials observed could be accounted for by local vegetation.

If there is sufficient upward air flow due to warmed air and other processes, the ragweed pollen may be carried aloft to high elevations. Pollen grains at 40,000 feet have been reported, and not infrequently there may be a higher concentration of pollen at an altitude of 4,000 to 6,000 feet than nearer the surface of the ground.[60] Although some grains may fall to the ground, horizontal dispersal over long distances can occur. As local air movement and turbulence diminish during the day, the pollen grains fall back to earth at a rate of 3 to 10 ft/min,[14,60] and a minimum surface air concentration occurs just prior to sunrise. Figures 7 and 8 in the Appendix show this diurnal ragweed pollen emission cycle

Other pollens also exhibit a diurnal periodicity.[75]

Acalypha pollen has been reported to reach a maximum between 6 and 7 a.m.,[79] Corylus at 1 p.m., Artemisia at 9 a.m., and Pinus at 3 to 5 p.m.[50] The patterns for timothy, corn, and castor bean plant are presented in Figure 9.

The ability of rain to cleanse the air of pollen has been investigated.[27] Pollen showed a rapid decrease in the air during heavy rain, with a partial recovery between separated showers. There was a possibility that a more or less continuous replenishment of the airborne pollen contamination into the storm was necessary in order for pollen to be found in the rain that fell more than a few minutes after the beginning of the rainfall.

During the ragweed season, daily pollen concentrations over much of the Eastern and Central United States may reach 350 to 1,000 grainsper cubic meter of air. During the peak day of the 1966 season, the pollen count in Ann Arbor, Mich., exceeded 4,400 grains per cubic meter.[83] Durham[33] in 1947 estimated that during the ragweed pollen season in the District of Columbia, an individual would inhale approximately 4,000 ragweed grains in 24 hours. However, during periods of maximum air contamination, the grass and ragweed pollen concentration may reach millions of grains per cubic meter. Raynor and Ogden[87] (1965) reported that the general background ragweed pollen concentration at the Brookhaven National Laboratory, New York, ranged between 10 and 150 grains per cubic meter. The area within a mile or two of the Laboratory is relatively ragweed-free, but at greater distances ragweed grows in normal profusion in all directions.

Table 16, Appendix, summarizes the monthly average counts obtained by the gravity slide method for the most common pollens found in the St. Louis area from March through September in both 1963 and 1964.[36] The pollen season begins in early spring with tree pollination, and continues through the summer with grass pollination, and into the fall with ragweed pollination. The weather conditions under which pollen usually was emitted were light winds, clear to partly cloudy skies, and at least moderate convection, all of which contribute to vertical movement of air.

Hornedo and Tillman[57] (1959) reported the results of a 2-year pollen survey in El Paso, Tex. Using the gravity slide method, they observed that weed pollens (Russian thistle, careless weed, and ragweed) predominated in early fall; tree pollens (elm, cedar, cottonwood, ash, pine, and mulberry) in late winter and early spring; and mulberry, pine, and oak in late spring. Peaks in pollen counts occurred in the fall (about September 30) and in February and April; and lows were in January, June, and November. The highest daily count (89 grains per cubic centimeter) occurred October 4, 1957 (see Figure 10, Appendix).

Many fungi are common in the air since their spores are adapted for aerial dissemination. Production of vast numbers of spores in periodic waves is characteristic of many fungi. Allergy to fungi may occur seasonally, depending upon climate and geography. Hormodendrum and Alternaria are especially abundant during May to September in the Central States.[20]

Morrow et al.[71] have summarized the most frequently isolated molds from 41 sampling stations across the country. No two stations had the same lists, but a basic group of dominant genera appeared to occur. These were:

Alternaria
Homodendrum
Aspergillus
Penicillium
Pullularia
Phoma
Trichoderma
Fusarium
Helminthosporium
Cryptococcus
Rhodotorula

Similar genera of fungi were observed in Tucson, Ariz.,[35] in Phoenix, Ariz.,[42] in Albuquerque, New Mex.,[31] and in Los Angeles, Calif.[97]

The airborne concentration of fungi changes from season to season, from day to day, and even from hour to hour. Table 17, Appendix, illustrates the hourly fluctuations of Alternaria spores observed by Pathak and Pady. Some fungi appear to have a diurnal periodicity.[79,81] One explanation offered for the latter fact is that--as, for example, in Cladosporum--a single crop of spores is produced per 24-hour period, maturing at night and ready to be released just before daylight. Morning turbulence produces a midmorning peak by carrying the spores into the air in large numbers,(for example, 100 per cubic foot (3,500 per cubic meter)). Decreasing air turbulence later in the day produces a late afternoon or early evening peak.[88] Pady[78] found fungi spores present in the atmosphere at an elevation of 150 feet throughout the year in Kansas, with peaks in July and August. In summer their number varied from 50 to 700 per cubic foot (1,765 to 24,700 per cubic meter), while in winter they ranged from 5 to 20 per cubic foot (175 to 700 per cubic meter).

4. ABATEMENT

The abatement and control of aeroallergens have been primarily directed at the control of ragweed. Ragweed grows very quickly in areas where the soil has been disturbed; it is not found in areas shaded by trees or in heavy growth of grass, shrubs, or ferns. If soil is not disturbed, grass will eventually crowd out ragweed. Although some ragweeds are annual plants, the seeds can remain viable for many years and ready to germinate once the soil is disturbed. Therefore, control of ragweed by pulling it up is not satisfactory, since the soil is thus disturbed and the growths may be heavier the following year. Control by cutting is satisfactory only if done prior to flowering; otherwise, flower heads will continue to develop and pollinate. Soil sterilants are toxic to most other plants as well as to ragweed; and if successful, their use leads to the problem of soil erosion.

Herbicides such as 2,4-D (dichlorophenoxyacetic acid salts) have been used successfully where applicable. Since 2,4-D is lethal to most broadleaf plants (including ragweed) and to vegetables, flowers, and some grasses, its use on crop acreage is limited.

The recommended application of 2,4-D is one-half pound per acre, although 0.1 pound per acre has also yielded good results.[39] It is best used when diluted in water (5 to 100 gallons per acre). The spraying program for ragweed should be initiated just before the flower buds open. The herbicide 2,4,5-T (trichlorophenoxyacetic acid), a compound similar to 2,4-D, has also been used. The potential side effects and toxicity of herbicides are discussed in a separate report of this series, "The Air Pollution Aspects of Pesticides."

Considerable money and effort have been expended by several municipalities in attempts to reduce or eliminate ragweed within their boundaries, but generally these attempts have not significantly changed pollen concentrations.[87] Walzer and Siegle[111] reported on the effectiveness of a ragweed eradication program in New York City. After the program was initiated in 1946, a 50 percent reduction in ragweed plants within the city was observed at the end of 4 years. However, the program did not produce any further decline during the next 5 years. Also, during this 9-year period there was no change in the pollen count from 30 stations in and around New York City (see Figure 11, Appendix). During certain seasons, pollen counted on a lightship in New York harbor, at a point 9 miles from the nearest land, amounted to as much as 45 to 60 percent of the pollen collected in New York City, and on some days exceeded those of the city. The data indicated that the city probably received as much windborn pollen from areas to the west as was generated locally. Furthermore, no differences were found on comparing the New York City counts and those from neighboring New Jersey and Connecticut, where no eradication programs were underway. These authors concluded that the elimination of ragweed pollen in the air cannot be accomplished on a local level, but that any program must be developed on a regional basis. Obviously, if the pollen entering a city from outside is enough to cause pollinosis in all susceptible individuals, local control is inadequate. On the other hand, if the background pollen reaching a given local area is low--that is, insufficient to cause symptoms in the population--eradication of any local sources would be a beneficial preventive measure which could be undertaken by a local authority. The latter situation prevailed in Detroit, where a ragweed control program was accomplished. Nearly all of the pollen observed in sampling counts was produced in the immediate vicinity. Local eradication of ragweed plants, therefore, was beneficial in controlling the pollen concentration.[39]

Some aeroallergens are troublesome only in close proximity to susceptible individuals. Eradication of the nearby source often can reduce the daily exposure to such a degree that the individual's threshold sensitivity is decreased and he will not experience severe symptoms with normal background levels. In particular, the allergenic effects traceable to trees, plants, and flowers can be avoided by not growing them in the yard. Similarly, some allergies can be prevented by not keeping pets that produce danders and by avoiding certain cosmetics.

Molds, like pollens, are found in the outside air and to some extent in the home. The concentration found in the home is associated with house dust which may also be allergenic to susceptible individuals. Many of the allergies due to molds arise from specific molds found in damp places in the home (e.g., basements). These can be reduced in concentration or eliminated by the use of disinfectants. Criep _et al._[21] have recommended the use of inexpensive Roccal (benzalkonium chloride) at 1:1,000 to 1:10,000 dilution as a spray, or 1:1,000 dilution of trioxymethylene (crystalline paraformaldehyde) as a wash solution or vapor for treating musty houses. Table 18, Appendix, lists other germicidal substances which can be used.

Another approach to the control of pollinosis has been for sensitive individuals to avoid contact with the pollen by remaining indoors as much as possible during the hay fever season. Since 67 percent of the ragweed pollen collected during 24 hours was found between 9 a.m. and 1 p.m., Smith and Rooks[102] (1954) have recommended that sensitive individuals seek "shelter" during those hours. However, Dingle[26] (1957) has demonstrated that ragweed and other pollens can penetrate the cracks around doorways and windows of the average house. The amount of penetration was dependent upon the meteorological conditions. Air-conditioned buildings give some relief to susceptible individuals, but most air systems are not designed for aeroallergen control. This is especially true of home systems where house dust and/or molds are involved. The air ducts harbor large quantities of dust and molds, and the filters usually are not adequate to remove them from the air stream. However, present-day technology is capable of adequately designing air systems which benefit sensitive individuals.[22]

Control of pollinosis is often accomplished by temporary or permanent departure of the individual from a given area to one which is free of the specific pollen to which he is sensitive. A map of the United States showing areas relatively free of ragweed pollen is shown in Figure 12, Appendix. Although moving has been of benefit to many, some individuals after moving may develop a sensitivity to a new local pollen, or a plant to whose pollen he was already sensitized may be introduced into the area as an ornamental plant.

Many susceptible individuals can be treated so that exposure to the aeroallergen does not produce symptoms or the symptoms are reduced in severity. Extracts of various allergens are available which can be injected in small amounts into susceptible individuals to desensitize them temporarily to the allergen. Some persons routinely undergo a preseasonal series of desensitizing injections and later develop few symptoms during the aeroallergen season. The antihistaminic drugs have been used quite extensively to alleviate the acute symptoms of hay fever. However, antihistamines have not been a cure-all, and some individuals react adversely to these medications.

5. ECONOMICS

Ridker[90] has stated that because in many cases there are either insufficient or no data concerning the number of persons with an illness and very little information concerning the cost of treatment, the economic loss due to the health effects of air pollutants is most difficult to estimate. This applies equally to the economics of aeroallergens. Ridker has attempted to place a conservative dollar value estimate on some diseases (Table 19, Appendix), with diseases other than asthma listed for comparative purposes. The costs of prescribed medicine for asthma and/or hay fever as reported by the National Health Survey are presented in Table 20 (Appendix).

Because of this difficulty in estimating the cost of effects on health, another approach is to consider the incidence and prevalence of the illnesses. The Allergy Foundation of America has estimated that 8 to 9 million people in the United States are adversely affected by seasonal hay fever.[55] The addition of nonseasonal sufferers would increase this figure. The National Health Survey has reported that the number of asthma and/or hay fever sufferers was over 14,000,000 in 1964.[3] It has been estimated that 5 to 10 percent of the untreated patients with hay fever develop bronchial asthma.[10] Some estimates place the number of work days lost each year due to hay fever at 25 million.

Data pertaining to the "limitation in activity" by asthma and/or hay fever sufferers as reported by the National Health Survey are shown in Tables 21 and 22 in the Appendix.

Besides the direct cost and discomfort associated with hay fever and bronchial asthma, there are secondary economic effects: the ensuing lack of sleep and fatigue lowers efficiency at work. Additional secondary economic consequences are the sedative effect of medications, the danger of a sneezing attack while driving an automobile or while operating some mechanical device which could be hazardous to others, and the fact that swollen respiratory passages are prone to bacterial overgrowth and infection which may continue far beyond the hay fever "season."

The death rate due to asthma for 1964-1966 compared to other selected causes of death is presented in Table 23, Appendix.

Of the aeroallergens, the pollens are the worst offenders, and ragweed pollen specifically is responsible for greater than 90 percent of the pollinosis in the United States. Some costs are available for the control of ragweed. Freedman[39] (1967) has reported that in New Hampshire in 1948, ragweed control cost about $2.00 for one mile of highway on both sides. This figure included labor, cost of the chemical, and truck mileage. In 1967, a similar control program along roadsides and rights-of-way, using a combination of chemical and mechanical measures, probably would have cost in the range of $5 to $10 per acre.[39] In open areas, such as pasture and wheat fields, the weed could have been controlled with 2,4-D at an annual cost of $1.50 per acre; in congested areas the cost of control by mechanical techniques or in combination with sprays would have been approximately $25 to $50 per acre.[39]

6. METHODS OF ANALYSIS

The methods used for the analysis of aeroallergen pollution are based primarily on microscopic observations of collected samples from the air. Basically, these procedures are qualitative, but a relative degree of quantitation is introduced by standardization of the procedure. Some quantitative procedures are used that sample a given volume of air, and the results are expressed in terms of a count per unit volume of air. Most of the procedures have been concerned primarily with pollen and molds; little attempt has been made to sample for the other aeroallergens.

6.1 Qualitative Methods

The "gravity slide" method for pollen sampling, first used by Durham[32] in 1946, was accepted as the standard procedure by the Pollen Survey Committee of the American Academy of Allergy[85] in the same year. This standard air sampling device consists of two circular parallel planes of polished steel 9 inches in diameter and 3 inches apart, with a slide holder raised 1 inch above the lower plane. It is supported by a 30-inch metal rod on a tripod laboratory stand. A petrolatum-coated slide is placed in the slide holder and exposed to the air on an unobstructed seven- to eight-story rooftop for 24 hours. The entire exposed area of the slide ($4.84\ cm^2$) is examined microscopically and the pollen counted. The count is divided by 4.84 and expressed as a count per square centimeter, or simply as a number. The count can be converted into short ragweed pollen grains per cubic yard by multiplying by the factor of 3.6; to giant ragweed by 3.87; to timothy by 1.14; to corn by 0.17; and so forth.[32]

The pollen count is determined (by many local authorities) by daily exposing a series of these Durham gravity slides at various sites in and about an area. Some slides may be exposed at ground level. The number of particles trapped on the slide is dependent upon wind conditions during the sampling period, and therefore, it is difficult to relate the counts to actual concentrations in the air. However, the pollen counts thus obtained, after several years, show a pattern of pollen concentration increase and decrease and correlate to some degree with the general incidence of hay fever in a given local area.

The gravity slide method for pollen determination has a number of limitations. In particular, the sampling is for a 24-hour period and does not give any indication of peak concentrations which might have existed at any time during the sampling period. Also, Ogden and Raynor[74] demonstrated that slides placed parallel to the airflow collect much more pollen than those placed at right angles, and this difference becomes greater at the higher wind speeds prevalent at greater heights. An increase of 3 to 4 miles per hour in wind speed may result in a 50 percent increase in the amount of pollen trapped.[2] Therefore, the gravity slide method yields values which may not be entirely comparable to neighboring sampling sites because sampling heights and wind speed and direction cannot be standardized.

6.2 Quantitative Methods

Several volumetric devices are available for drawing a measured amount of air (using a vacuum pump) into a sampler. The intent here is to determine as accurately as possible the actual concentration present in the air at any given time. A photoelectric, continuous-recording particle sampler has been used by Smith and Rooks (1954) for studying the diurnal fluctuations of airborne ragweed pollen.[102] Raynor[86] made use of a membrane filter device with an attached timer and measured air intake to obtain a series of sequential pollen samples. The membrane filters were then viewed through a microscope and the counts determined. The Hirst Spore Trap draws a measured amount of air through an orifice, and the pollen is impacted on a microscope slide moved past the orifice at a rate of 2 mm/hr by a clock mechanism. A 24-hour sample thus can be obtained, but the deposition has been spaced in time along the slide.[56]

Volumetric sampling devices have presented the problem of isokinetic sampling. That is, with volumetric samplers, the intake opening must be continuously oriented into the wind, and the airflow through the sampler must be equal at all times to the wind speed in the free air approaching the intake. If these conditions are not met, a true representative sample cannot be obtained for particles the size of pollens.[113]

Because the use of volumetric samplers is too difficult in routine pollen sampling, the simple Durham gravity slide method has remained the standard technique in spite of its deficiencies. Although it is inaccurate for short-term (1 day or less) measurements, it has been satisfactory for determining seasonal patterns. However, a number of devices have been devised which attempt to retain simplicity but yet improve upon the gravity slide method. The simplest sampler has been a vertically-oriented wire of about 1 mm in diameter which is placed in the air stream containing pollen. The air can go around the wire but the pollen is impacted on the surface. The wire is then examined through a microscope and the pollen grains counted. An improvement upon this has been the flag sampler.[51] It consists of an ordinary household pin set in a glass bearing in which it moves freely. It has a flag of transparent tape wound about it that works like a weather vane to keep the coated leading edge of the pin facing into the wind. Particles unable to follow the air stream around the curved surface of the pin impact upon it and are counted by means of a microscope. A similar device uses a larger wind vane to keep the edge of a microscope slide facing into the wind to act as the trapping surface. Such samplers are inexpensive and are suitable for use when a large number of samples are to be taken. However, their disadvantages are that they are efficient only when there is some wind (at least 5 m.p.h.), and the impaction surfaces are quickly covered and require frequent changes. Also, the wind velocity and fluctuations need to be known, which requires the use of a separate recording anemometer.

Another approach to impaction sampling has been to mechanically move an adhesive-coated surface through the air to be sampled. The rotorod sampler[14] consists of two vertical rods (plastic or metal) rotated about a vertical axis approximately 2 inches away at a speed of about 2,000 rpm. The coated collecting surface of the rods moves at a tangential speed of approximately 25 mph, which is higher than most air velocities sampled and thereby has a relatively high collection efficiency independent of wind speed. The rods are examined through the microscope and pollen counts made. Modifications of this device have been the rotobar,[51] with a bar-shaped surface used instead of a rod, and the rotoslide,[74] which uses a microscope slide. The main disadvantage of these samplers has been that a high concentration of pollen can build up on the impaction surface in a short time (an hour or less) and, therefore, frequent changing is required when continuous sampling is desired. To obviate this difficulty, the rotodisk sampler[15] has been devised, which substitutes disks for the rods. The vertical edge of the disk is covered except for a small slit, and a timing mechanism automatically shifts the slit to expose a fresh sampling surface.

Fungi have also been sampled by the methods given above. As the pollen are being counted, some investigators may also count mold spores. However, fungi lend themselves to other sampling procedures that utilize growth of the organisms as a means of measurement. The basic methods are:

(1) Sedimentation:[89] In this simple method of sampling airborne organisms, the suspended particulates are allowed to settle on plain surfaces or on surfaces coated with a nutrient growth medium. This method yields information on the total number of viable particles that have settled out during the given sampling period of time.

(2) Impingement into liquids:[19,37,45,72] Air is drawn through a small jet and is directed against a liquid surface, the suspended fungi being collected in the liquid. Because of the agitation of the particles in the collecting liquid, aggregates are likely to be broken up. Therefore, the counts obtained by this method tend to reflect the total number of individual cells in the air and are higher than the value obtained by other methods.

(3) Impaction onto solid surfaces:[6,28] Air is

drawn through a small jet(s) and the particles are deposited on dry or coated solid surfaces, or on an agar nutrient. This method has been used to determine total cellular numbers, size distribution, total viable numbers, and variation in concentration per unit of time during a long sampling period.

(4) Filtration:[70,73,95,108] The particulates are collected by passage of the air through a filter which can be cellulose-asbestos paper, glass wool, cotton, alginate wool, gelatin foam, or membrane material. The particulates are washed from the filters and assayed by appropriate microbiological techniques. Since the viability of the organisms can be detrimentally affected by dehydration in the air stream, the results may be biased in this method.

(5) Centrifugation:[93,114] The particulates are propelled by centrifugal force onto the collecting surface, which can be glass or an agar nutrient. Particulate size and particulate concentration can be obtained by this method.

(6) Electrostatic precipitation:[66] Particles are collected by drawing air at a measured rate over an electrically charged surface of glass, liquid, or agar. The number of particles or viable number is then determined.

(7) Thermal precipitation:[65] The organisms are collected on surfaces by means of thermal gradients. The design is based on the principle that airborne particles

are repelled by hot surfaces and are deposited on colder surfaces by forces proportional to the temperature gradient. The particle size distribution can then be determined.

7. SUMMARY AND CONCLUSIONS

Aeroallergens are airborne materials which elicit a hypersensitivity or allergic response in susceptible individuals. The major effects of aeroallergens on human health are the production of allergic rhinitis and bronchial asthma. If the symptoms of allergic rhinitis occur during a particular season of the year, it is commonly called hay fever. It has been estimated that there are 10 to 15 million hay fever sufferers in the United States and that 5 to 10 percent of the untreated patients will develop bronchial asthma.

The common aeroallergens affecting human health are pollens of wind-pollinated plants, molds, house dust, and a miscellaneous group of vegetable fibers, cosmetics, paints, and others. The pollens are the most important of the entire list, and ragweed provides the most common of the pollens. More than 90 percent of the pollinosis occurring in this country is due to ragweed pollen.

Laboratory animals are used routinely in allergy studies, but exposure is usually by injection; most animals do not exhibit allergenic reaction to inhalation of aeroallergens. There is no evidence that aeroallergens have adverse effects on plants or materials.

Insufficient information exists to establish environmental air standards for the aeroallergens. Daily pollen counts are taken and pollen indexes derived in many local areas of the country by the use of a standardized procedure. However, because many variables are involved, these values are used more as guidelines than as standards. Generally, indexes of 5 to 15 are considered moderate, and acute hay fever symptoms last only a few days. Indexes above 15 are indicative of heavy pollen concentrations, and an index of 25 or more on any given day will usually cause severe symptoms of hay fever in most of the susceptible population. These values are relative, however, and may vary considerably between local areas.

Ragweed establishes itself readily in freshly turned soil, and therefore is found in abundance both in farmlands and in urban areas in most parts of North America. Of the other aeroallergens, the molds are ubiquitous; their usual habitat is the soil and dust, and they become airborne through local air disturbances. House dust consists of small organic particulates. Because it is found in every indoor environment, house dust is probably the most common aeroallergen after pollens. Danders and other similar aeroallergens are found in the air close to their source, and their concentration in the air is therefore limited. They are allergenic to humans when the source is in close proximity to the susceptible individual.

The potential of other air pollutants to act synergistically with the natural allergens has become a new area of study in recent years. Several investigators have observed an increase in hospital admissions for bronchial asthma on days of high air pollution.

There are many materials which are aeroallergenic to sensitized individuals. However, some of the allergens are incorporated into products in such a way that their presence cannot always be recognized. Stuffing in pillows, mattresses, and toys may be of feathers, kapok, or other materials that can be highly allergenic.

The emission and dispersal of ragweed pollen have been studied in much detail. It has been found that pollen release occurs primarily in the early morning, and once the pollen is airborne, its dispersal is dependent upon horizontal and vertical air movements. If there is little air movement, dispersal of the pollen from a given source may be negligible. However, upward air flow can carry pollen up to high elevations, whereas horizontal air movements can carry the pollen great distances in all directions. During the ragweed season, daily pollen concentrations over much of the Eastern and Central United States commonly reach 350 to 1,000 grains per cubic meter of air.

The abatement and control of aeroallergens have been concentrated on ragweed. Considerable money and effort have been expended by local municipalities in attempting to reduce the pollen concentration in the air by reducing the ragweed plant density. Herbicides such as 2,4-D have been used extensively for this purpose. However, many of the eradication programs have had little success, primarily because windborne pollen from outside the control area usually has entered the city in sufficient quantities to cause pollinosis in the local susceptible population.

The economic costs incurred by the effects of and the control of aeroallergens cannot be adequately estimated. Insufficient data are available regarding the costs of allergic illnesses, and there are no estimates for the cost of abatement on the regional scale that would be required for adequate control.

The standard procedure for the analysis of pollens recommended by the Pollen Survey Committee of the American Academy of Allergy is the gravity slide method. Basically, the procedure involves exposing an adhesive-coated slide to the air for 24 hours, following which it is examined microscopically and a count made of the particles deposited.

Based on the material presented in this report, further studies are suggested in the following areas:

(1) Additional investigations are needed concerning the cause of periodic peak occurrences of bronchial asthma and associated illnesses.

(2) There is need for a relatively inexpensive automatic device for both research and routine sampling and

and counting of pollen and other aeroallergens.

(3) A cost benefit analysis of regional versus local ragweed control programs is warranted.

(4) Better estimates are needed of economic costs associated with the illnesses caused by aeroallergens.

(5) The design of air systems, especially for homes, should be evaluated and improved for indoor control of aeroallergens.

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APPENDIX

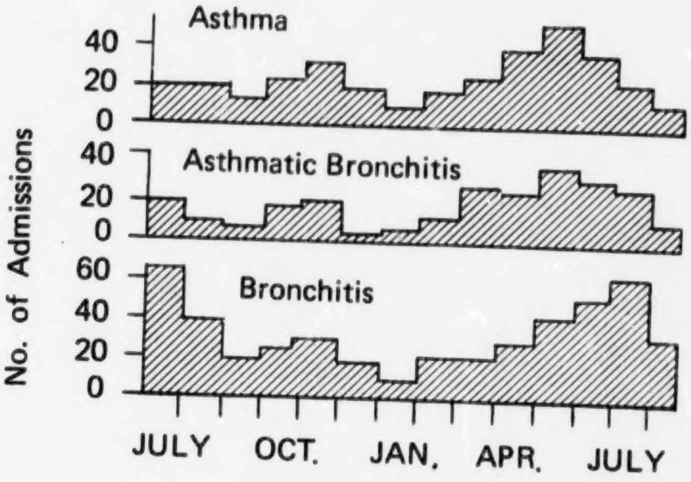


FIGURE 1

Seasonal Variations in Respiratory Illness. Monthly admissions to the Brisbane Children's Hospital in Australia, 1955-58, for asthma, asthmatic bronchitis, and bronchitis.[23]

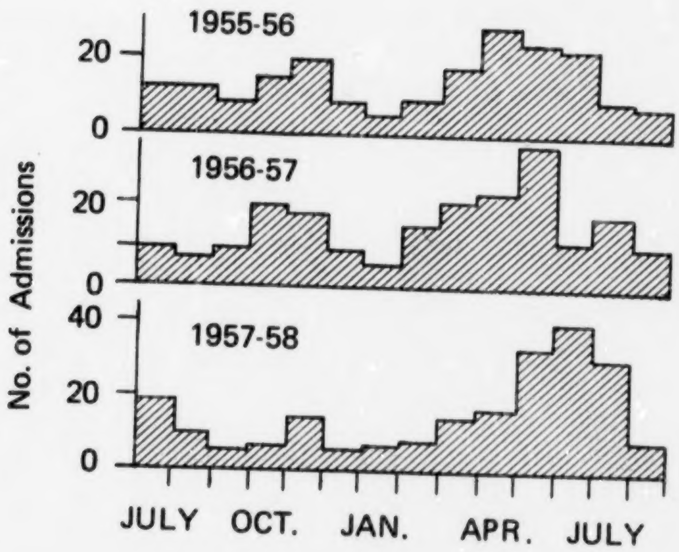


FIGURE 2

Seasonal Fluctuations in Respiratory Illness for Several Years. Monthly admissions for asthma (including asthmatic bronchitis) to the Brisbane Children's Hospital in Australia for each year of the study. The spring and autumn waves occurred in each year, with some variation in height and time.[23]

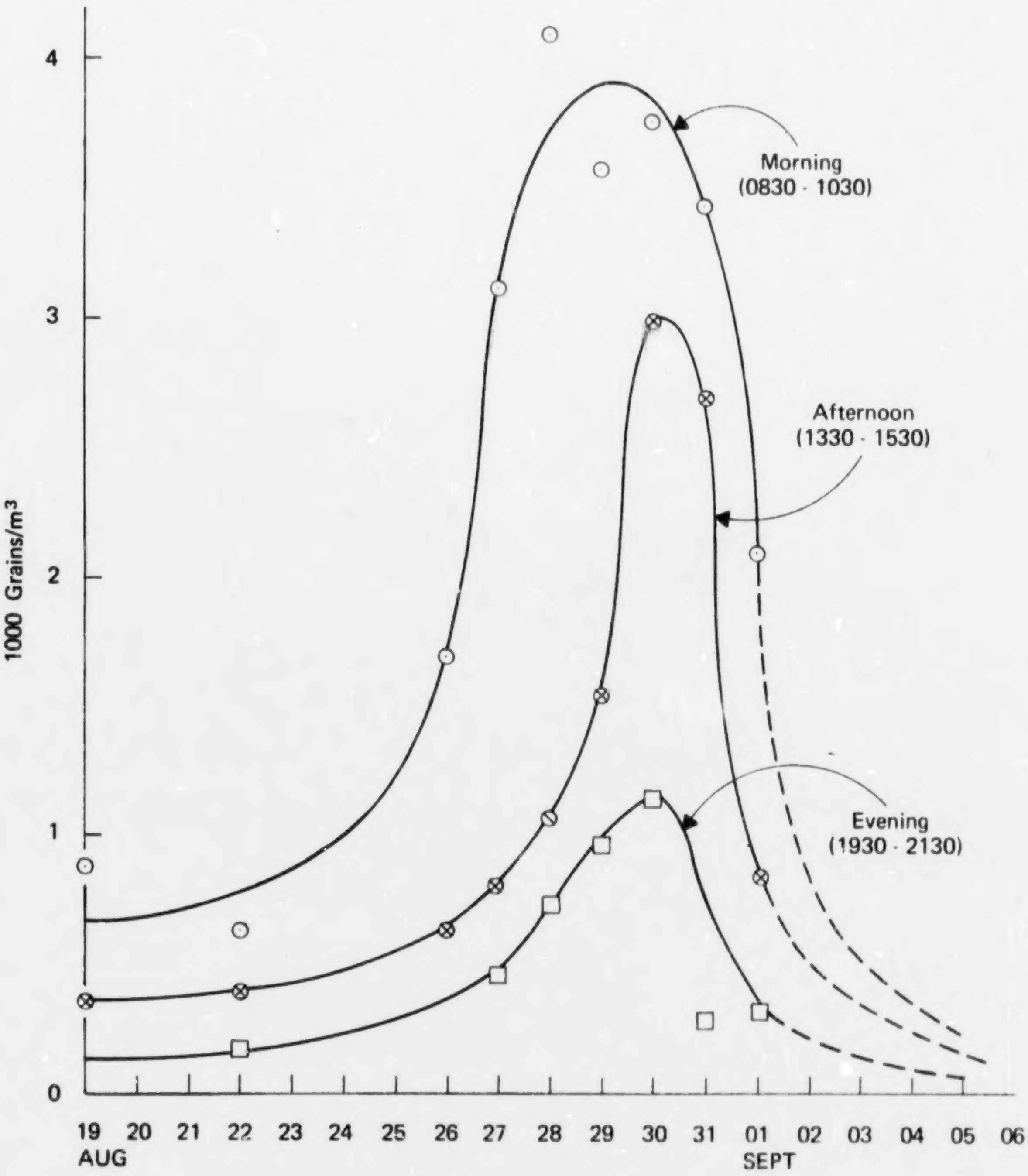


FIGURE 3

Ragweed Pollen Concentrations During the 1958 Ragweed Season at and near Ann Arbor, Mich.[98]

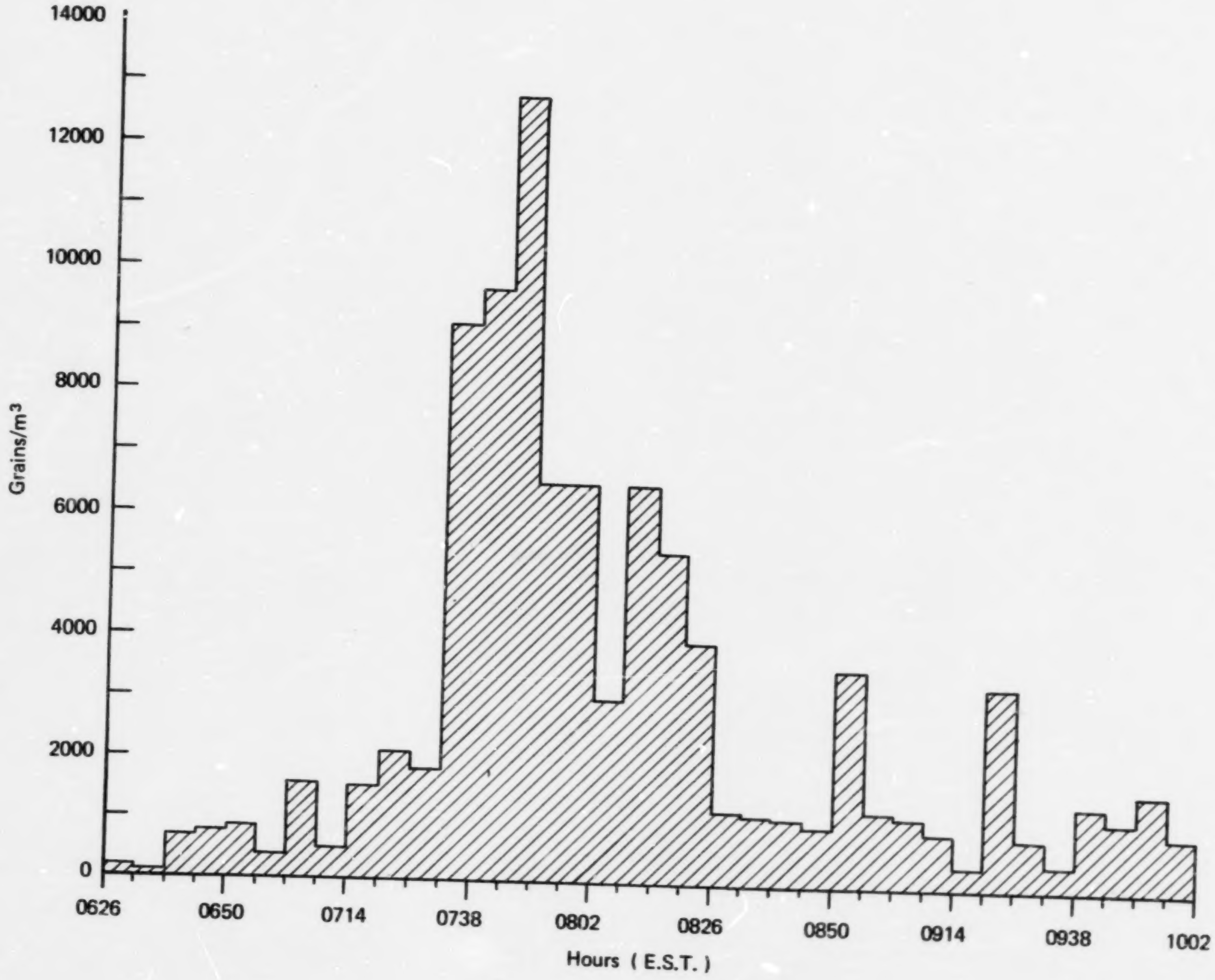


FIGURE 4

Variations in Ragweed Pollen Concentrations Close to the Pollen Source.[76]

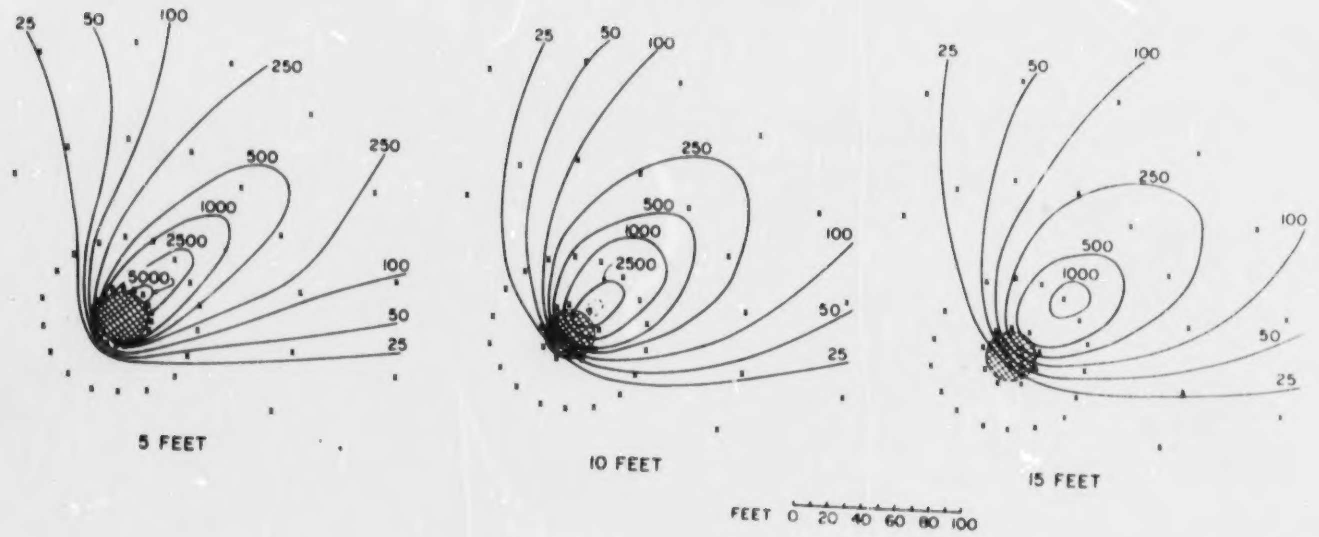


FIGURE 5

Ragweed Pollen Concentration Patterns (grains/m^3). These patterns were observed at heights of 5, 10, and 15 ft in an east field plot, August 10-11, 1961[87]

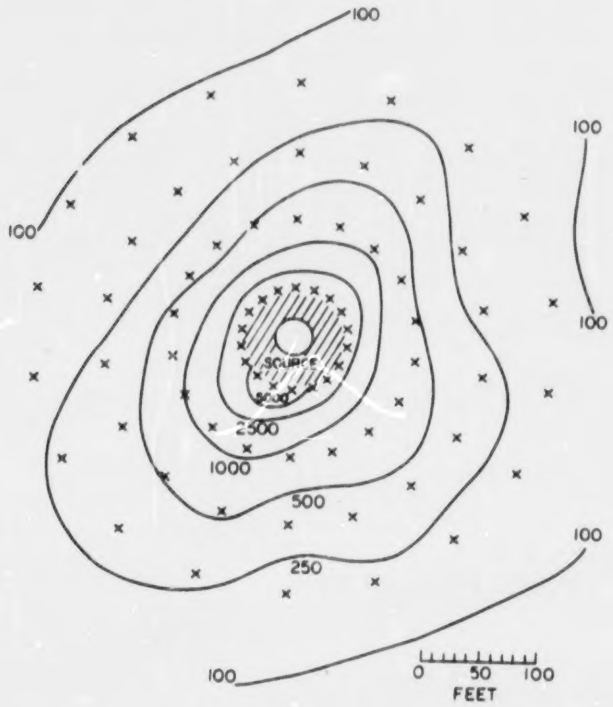


FIGURE 6

Seasonal Average Concentration of Ragweed Pollen (grains/m^3). Sampled at 5 ft, east field plot, in-season, 1961.[87]

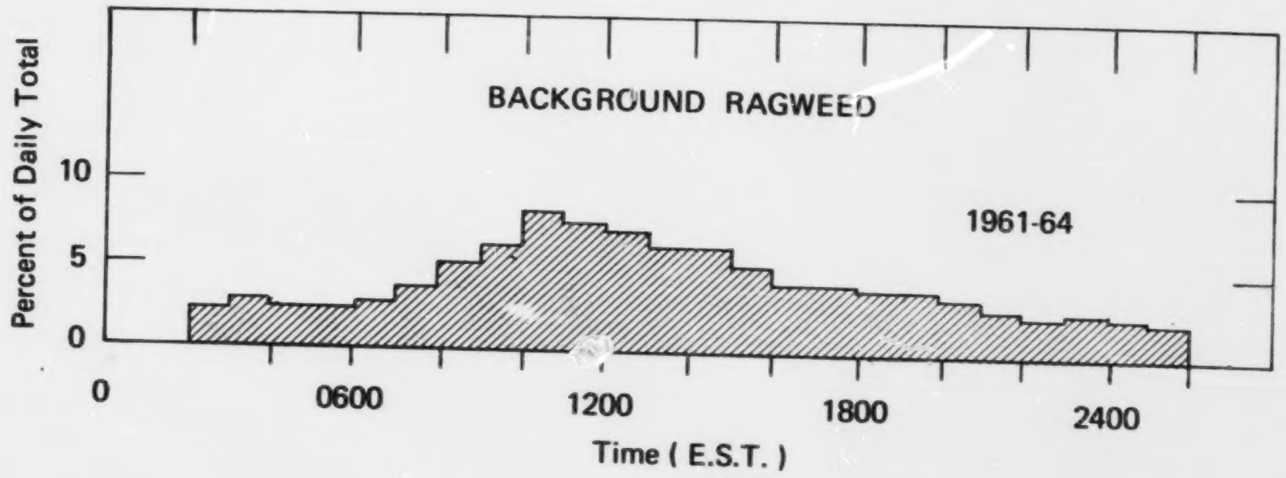


FIGURE 7

Diurnal Ragweed Pollen Concentration Patterns at a Location Distant from a Local Source[76]

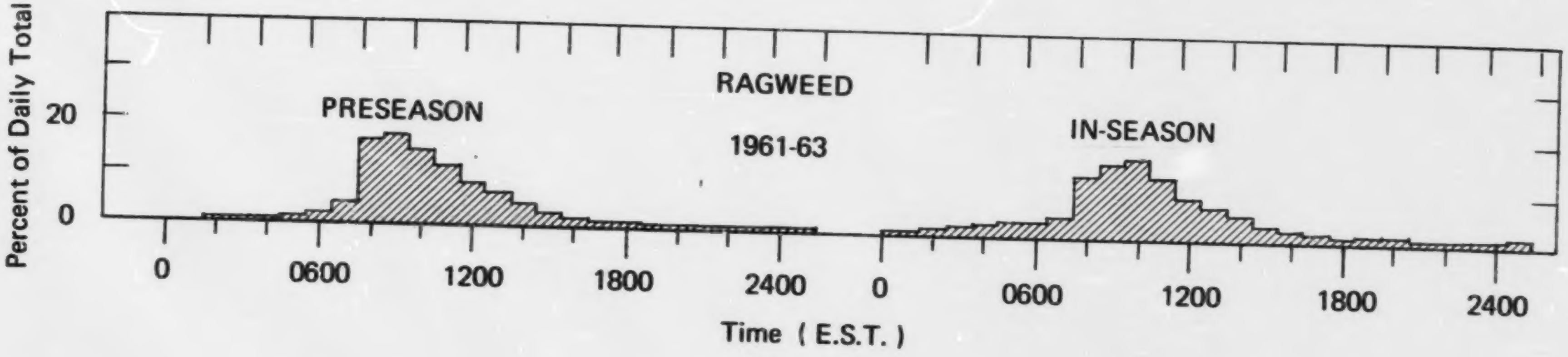


FIGURE 8

Diurnal Pollen Emission Patterns from Fields of Ragweed[76]

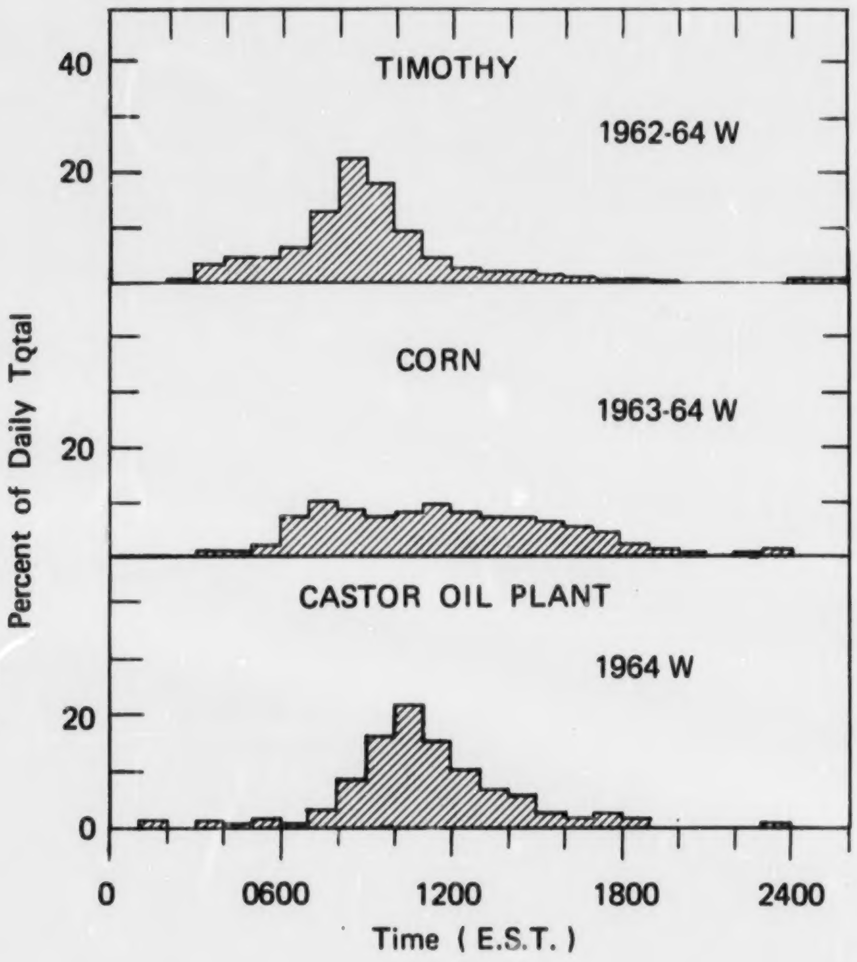


FIGURE 9

Diurnal Pollen Emission Patterns from Fields of Timothy, Corn, and Castor Bean Plant[76]

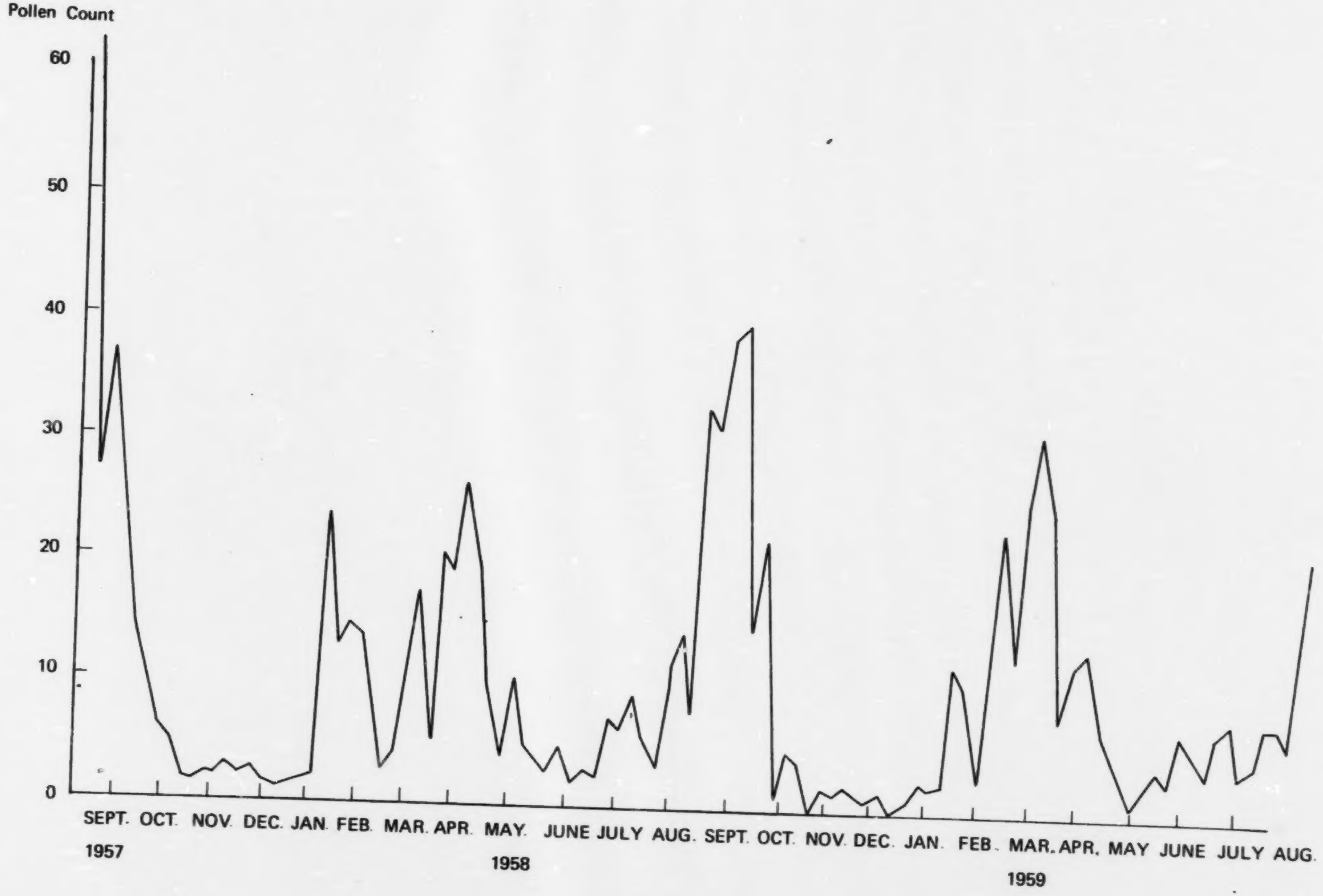


FIGURE 10

Weekly Average Pollen Counts, El Paso, Tex.[57]

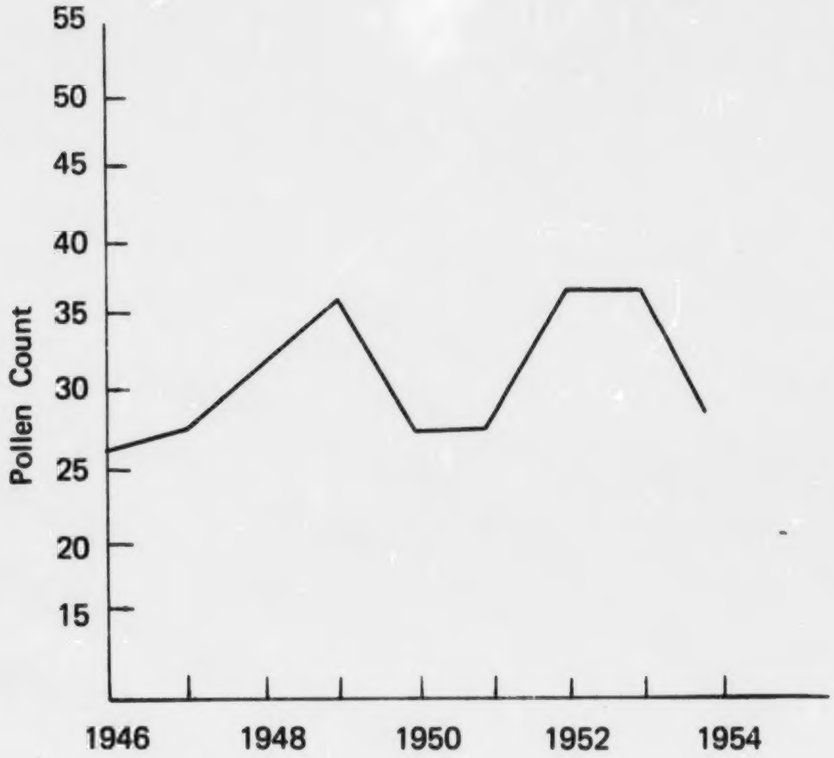
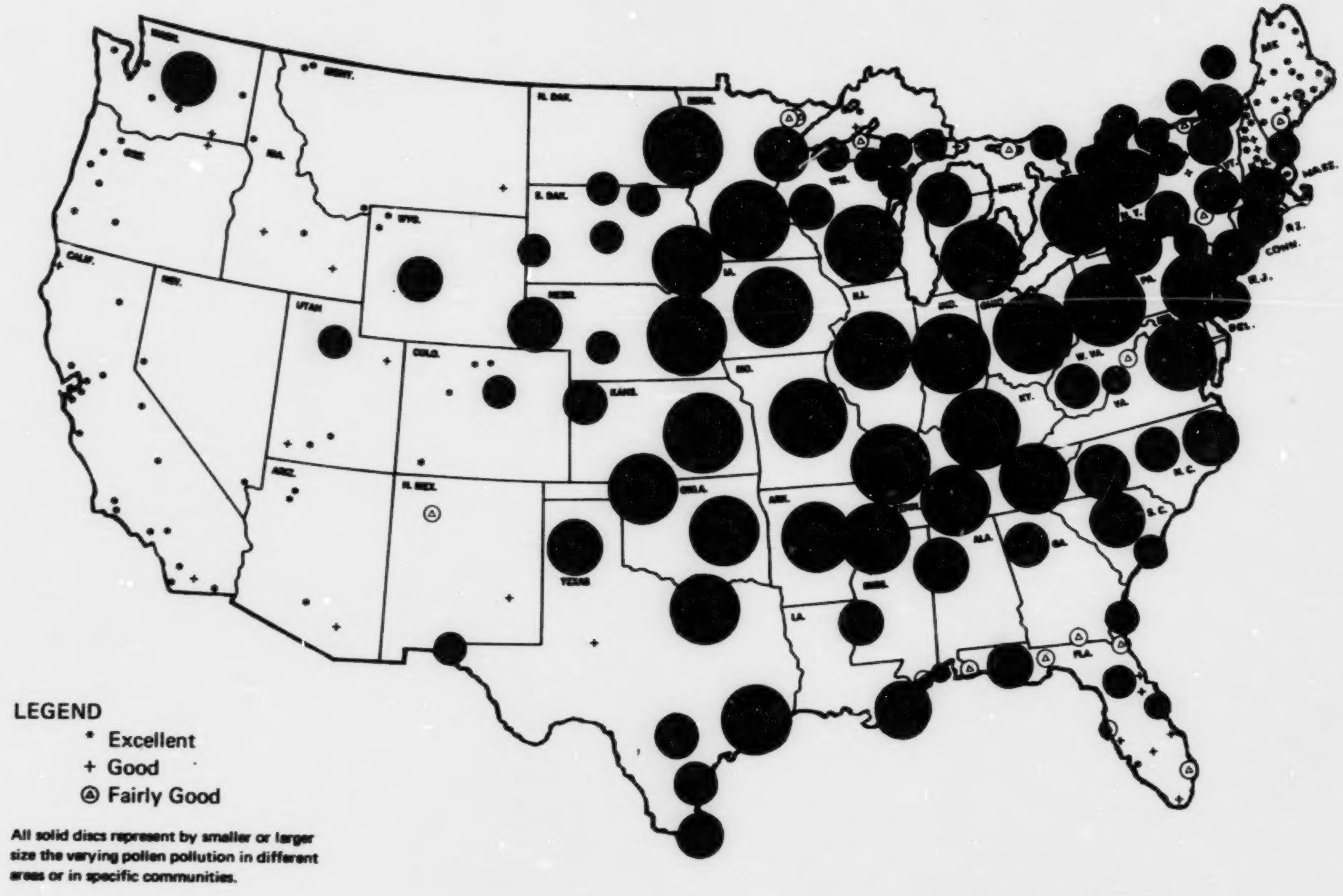


FIGURE 11

Pollen Count for New York City, 1946-1954[111]


WASH.
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MINN.
ORE.
IDA.
S. DAK.
WYO.
WIS.
MICH.
N.Y.
ME.
VT.
MASS.
R.I.
CONN.
N.J.
DEL.
CALIF.
NEV.
UTAH
NEBR.
IA.
ILL.
IND.
OHIO
PA.
W. VA.
VA.
KY.
COLO.
KANS.
MO.
ARIZ.
N. MEX.
OKLA.
ARK.
TENN.
N.C.
S.C.
ALA.
GA.
MISS.
LA.
FLA.
TEXAS
LEGEND
* Excellent
+ Good
Ⓐ Fairly Good
All solid discs represent by smaller or larger size the varying pollen pollution in different areas or in specific communities.

FIGURE 12

Ragweed Pollen Refuges in the United States[34]

TABLE 1

COMMON AEROALLERGENS[52,64]

Aeroallergens	Source
Pollens	Wind-pollinated plants, grasses weeds, and trees
Molds	Usually saprophytic, prevalence depending upon humidity
Danders	Feathers of chickens, geese, ducks; and hair of cats, dogs, horses, sheep, cattle, laboratory animals, and humans
House dust	A composite of all dusts found about the home
Miscellaneous	
Vegetable fibers and dusts	Cotton, kapok, flax, hemp, jute, straw, castor bean, coffee bean, oris root, rye, wheat
Cosmetics	Wave set lotions, talcs, perfumes, hair tonics
Insecticides	Insecticides containing pyrethrum as a common ingredient
Paints, varnishes, and glues	Linseed oil and organic solvents

TABLE 2

COMMON WIND-POLLINATED PLANTS[11]

Common Name	Botanical Name	Diameter (microns)	Specific Gravity
Giant ragweed	*Ambrosia trifida*	19.25	0.52
Burweed marsh elder	*Iva xanthifolia*	19.3	0.79
Short ragweed	*Ambrosia elatior*	20.0	0.55*
False ragweed	*Franseria acanthicarpa*	22.0	0.75
Marsh elder	*Iva ciliata*	23.0	0.58
Southern ragweed	*Ambrosia bidentata*	23.0	0.50
Western ragweed	*Ambrosia psilostachya*	26.4	0.57
Cocklebur	*Xanthium commune*	27.0	0.45
Russian thistle	*Salsola pestifer*	23.6	0.90
Palmer's amaranth	*Amaranthus palmeri*	25.8	1.02
Western water hemp	*Acnida tamariscina*	27.5	1.01
Mexican fireweed	*Kochia scoparia*	32.7	0.97
Annual sage	*Artemisia annua*	20.4	1.02
Tall wormwood	*Artemisia caudata*	21.0	1.04
Sagebrush	*Artemisia tridentata*	25.85	1.03
Nettle	*Urtica gracilis*	14.0	0.77
Red sorrel	*Rumex acetosella*	21.45	0.78
Hemp	*Cannabis sativa*	25.0	0.82
English plantain	*Plantago lanceolata*	27.5	0.97
Bluegrass	*Poa pratensis*	28.0	0.90
Bluegrass	*Poa pratensis*	30.0	0.90
Bermuda grass	*Capriola dactylon*	28.5	1.01
Orchard grass	*Dactylis glomerata*	34.0	0.91
Timothy	*Phleum pratense*	34.0	0.90
Rye	*Secale cereale*	49.5	0.98
Corn	*Zea mays*	90.0	1.00
Sycamore	*Platanus occidentalis*	22.22	0.92
Mountain cedar	*Juniperus sabinoides*	22.8	1.08
Hazelnut	*Corylus americana*	23.6	1.09
Birch	*Betula nigra*	24.6	0.94
Alder	*Alnus glutinosa*	26.0	0.97
Ash	*Fraxinus americana*	27.1	0.90
Cottonwood	*Populus virginiana*	30.0	0.79
Elm	*Ulmust americana*	31.2	1.00
Bur oak	*Quercus macrocarpa*	32.3	1.04
Shingle oak	*Quercus imbricaria*	33.1	1.04

*(1.3).

(continued)

TABLE 2 (Continued)

COMMON WIND-POLLINATED PLANTS[11]

Common Name	Botanical Name	Diameter (microns)	Specific Gravity
Walnut	*Juglans nigra*	35.75	0.93
Beech	*Fagus grandifolia*	44.0	0.94
Hickory	*Carya ovata*	45.0	0.79
Scotch pine	*Pinus sylvestris*	52.0	0.45
Bull pine	*Pinus ponderosa*	60.0	0.45

TABLE 3

POLLEN SEASONS THROUGHOUT THE UNITED STATES[60]

Location	Tree	Grass	Ragweed	Amaranth	Russian thistle	Salt bush	Sage	Chenepod	Dock	Plantain	Kochia	Hemp	Elm
Alabama Montgomery	1/15 6/7	4/1 10/1	9/1 10/7										
Arizona Phoenix	2/1 5/1	4/1 11/1	9/15 11/1	5/15 12/22									
Kingman			8/1 10/15		6/15 10/1	6/15 10/1							
Arkansas Little Rock	2/7 5/7	5/15 10/1	8/15 10/15										
California North Western	2/1 7/1	4/1 8/7	7/1 11/15			4/1 9/22	7/1 11/15	4/1 9/22					
Southern Area	1/15 3/1	3/1 12/1	7/7 11/1		7/1 11/1		7/7 11/1						
San Francisco Bay Area	2/15 6/15	4/1 1/1	6/22 11/1				6/22 11/1		5/1 9/1	5/1 9/1			

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
Colorado Denver	3/15 4/15	6/7 7/15	8/1 10/1		7/7 9/15		8/15 10/1				7/7 9/15		
Connecticut	3/15 5/22	5/15 7/15	8/15 9/15										
Delaware	3/1 5/15	5/15 7/7	8/15 10/1										
District of Coumbia Washing-ton	2/1 5/15	5/15 7/7	8/15 10/1										
Florida Miami	2/1 4/1	3/1 6/1	5/15 9/15										
Tampa	2/7 5/15	1/1 12/31	8/7 12/1										
Georgia Atlanta	1/15 5/7	5/1 9/15	8/15 10/1										

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
Idaho Southern Area	3/15 5/1	5/1 8/7	8/15 9/22		7/7 10/1	7/7 10/1	7/22 10/15						
Illinois Chicago	3/15 6/1	5/22 7/15	8/15 10/1										
Indiana Indianapolis	3/15 6/7	5/15 7/7	8/15 10/1										
Iowa Ames	3/15 5/15	5/15 9/1	8/15 10/1										
Kansas Wichita	3/1 6/1	5/1 6/15	8/15 10/1	7/15 10/1	7/15 10/1								
Kentucky Louisville	3/1 6/1	5/15 7/1	8/15 10/1										
Louisiana New Orleans	1/1 4/1	4/1 12/1	8/15 10/22										

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
Maine	4/1 6/1	5/15 7/7	8/7 9/22										
Maryland Baltimore	3/1 5/7	5/7 7/1	8/15 10/1										
Massachusetts Boston	4/1 6/1	5/15 7/15	8/15 10/1										
Michigan Detroit	3/1 6/1	5/15 7/15	8/15 10/1										
Minnesota Minneapolis	4/1 6/1	5/22 7/7	8/15 9/22	6/1 10/1				6/1 10/1					
Mississippi Vicksburg	2/1 5/1	5/7 10/1	9/1 10/7										
Missouri St. Louis Kansas City	3/1 6/1	5/15 7/7	8/7 10/1										

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
Montana Miles City	4/1 6/1	5/1 9/22	8/1 10/7		7/7 9/7		8/1 10/7						
Nebraska Omaha	3/1 6/1	5/15 7/15	8/15 9/22		7/7 9/7							8/1 9/7	
Nevada Reno	4/1 6/1	6/1 8/1	8/22 10/1		7/1 10/1	7/1 10/1	8/1 10/7						
New Hampshire	4/1 6/1	5/15 7/22	8/15 10/1										
New Jersey	3/15 6/1	5/15 7/15	8/15 10/1										
New Mexico Roswell	3/15 5/1	5/15 10/15	8/22 10/22	7/1 10/1		7/1 10/1	8/22 10/22						
New York New York	3/15 6/1	5/15 7/15	8/15 10/1										
North Carolina Raleigh	2/1 6/1	5/15 7/15	8/15 10/1										

(continued)

TABLE 3 (Continued

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
North Dakota Fargo	4/1 6/1	6/1 8/1	7/22 9/7		7/1 9/15		8/15 9/22						
Ohio Cleveland	3/15 6/15	6/1 7/15	8/15 9/22										
Oklahoma Oklahoma City	2/15 6/15	5/1 10/1	8/22 10/7	7/1 10/7									
Oregon Portland	2/22 5/1	4/22 9/1							5/1 10/1	5/1 10/1			
Area East of Cascade Mountains	3/15 4/15	5/7 7/1	8/15 9/15		7/7 10/1	7/7 10/1	8/22 10/1						
Pennsylvania	3/15 5/15	5/7 7/15	8/15 10/7										
Rhode Island	3/15 6/1	5/22 8/1	8/15 10/1										

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Tree	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
South Carolina Charleston	2/15 5/22	5/15 8/7	8/15 10/7										
South Dakota	3/1 5/1	5/15 7/15	7/22 10/1		7/1 10/1		8/22 10/1						
Tennessee Nashville	2/22 5/22	5/1 9/7	8/22 10/7				9/7 10/1						7/7 10/1
Texas Dallas	12/15 5/1	4/1 10/1	9/1 10/1										8/22 10/1
Utah Salt Lake City	4/1 5/22	5/7 7/22	8/15 10/1		7/15 9/15		9/7 10/11						
Vermont	4/1 6/1	5/22 7/15	8/15 9/22										
Virginia Richmond	2/1 6/15	5/15 7/15	8/15 10/1										

(continued)

TABLE 3 (Continued)

POLLEN SEASONS THROUGHOUT THE UNITED STATES

Location	Trees	Grass	Rag-weed	Ama-ranth	Russian thistle	Salt bush	Sage	Chene-pod	Dock	Plan-tain	Kochia	Hemp	Elm
Washington Seattle	2/22 5/1	4/22 10/15							5/1 10/15	5/1 10/15			
Eastern Area	3/15 4/15	4/22 7/7	8/15 9/22		7/15 10/1	7/15 10/1	8/22 10/1						
West Virginia	3/15 6/15	5/22 7/15	8/15 9/15										
Wisconsin Madison	4/1 6/1	6/1 7/22	8/15 9/22										
Wyoming	3/22 5/1	6/7 8/1	7/7 9/15		7/1 9/15		8/15 10/15						

TABLE 4

MOST COMMON AEROALLERGENIC FUNGI[20,52]

Alternaria

Aspergillus

Botrytis

Cladosporium

Curvularia

Epicoccum

Fusarium

Helminthosporium

Hormodendrum

Macrosporium

Penicillium

Phoma

Pullalaria

Spondylocladium

Stemphyllum

TABLE 5

SUMMARY OF DIFFERENCES BETWEEN HOSPITAL ADMISSION RATES FOR DAYS OF HIGH AND DAYS OF LOW AIR POLLUTION*[106]

Disease Groupings	Oxi-dants	CO	SO_2	NO_2	NO	Oxides of Nitrogen	Ozone	Oxi-dant Precur-sor	Partic-ulate Matter	Temper-ature	Humid-ity
Allergic disorders	x			x		x			x	x	+
Acute upper respiratory infections	–	–	x	+	+	x	$\underline{x}$	x	x	$\underline{x}$	
Pneumonia	x	+		x			x	x	x	+	—
Bronchitis		+	+	x	x	x	—	x	x		$\underline{x}$
Diseases of tonsils and adenoids	$\underline{x}$	—	+		—		—	—	—	$\underline{x}$	
Other diseases of respiratory system	x	x		+				x	x	x	

*Differences of 5 percent or less are not shown.
Differences of 6-10 percent indicated by + or —.
Differences of 11 percent or more indicated by x or $\underline{x}$ (if negative).

APPENDIX

Table 6

PERCENTAGE DISTRIBUTION OF EMERGENCY VISITS BY MONTH, 1960[9]

Hospital and City	Month												Total No. of Cases	Percent
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
Harlem New York	8.45	7.58	7.82	5.82	6.29	5.89	5.12	7.11	8.09	12.85	13.40	11.58	10,684	100
Metropolitan New York	7.49	7.33	7.93	5.96	6.55	5.95	5.58	5.73	7.47	14.76	14.41	10.82	5,432	100
D.C. General Washington	9.60	6.33	8.25	6.44	5.99	5.31	6.55	4.97	7.91	14.69	13.67	10.28	885	100
General Philadelphia	7.98	7.38	5.57	5.65	7.55	6.91	7.81	8.20	7.51	13.29	13.72	8.42	2,317	100
Cook County Chicago	5.95	4.93	4.64	5.53	7.09	7.72	6.30	7.46	10.30	17.34	12.78	9.96	3,795	100
St. Francis Evanston	3.70	2.47	7.41	3.70	7.41	8.64	8.64	9.88	17.28	18.52	6.17	6.17	81	100
Thomas Memorial Charleston	7.76	5.94	5.02	8.68	3.20	5.02	4.57	9.13	15.07	10.50	13.24	11.87	219	100
Michael Reese Chicago	7.23	6.54	5.22	6.41	6.60	6.22	7.10	8.04	7.92	15.65	12.51	10.56	1,591	100
De Paul Norfolk	6.22	6.73	2.85	5.96	8.81	7.77	6.48	4.40	9.07	14.77	14.51	12.43	386	100
Charity New Orleans	5.94	5.12	4.08	5.22	8.18	5.89	8.00	6.64	7.93	15.01	17.10	10.89	8,163	100

TABLE 7

AVERAGE DAILY NUMBER OF EMERGENCY CLINIC VISITS FOR ASTHMA, 1962, 1961, 1957[47]

Year	Hospital		
	Bellevue	Metropolitan	Harlem
1962			
September 1-18	12.0	23.2	39.7
September 19-26*	21.0	42.4	60.3
September 27-30	12.3	30.3	57.0
1961			
September 1-15	7.4	27.3	14.5
September 16-19*	30.5	60.8	44.8
September 20-30	12.9	40.2	24.1
1957			
September 16-25	6.6	9.0	25.0
September 26-30*	16.2	24.0	52.4
October 1-15	9.7	11.2	26.3

*Critical period.

TABLE 8

AVERAGE DAILY NUMBER OF EMERGENCY CLINIC VISITS FOR ASTHMA, SEPTEMBER, 1964, 1965[49]

Location and Time	Average Visits Per Day	Percent Increase	Probability
1964			
Bellevue Hospital			
September 1-12	13.3		
September 13-16*	28.0	+110.5%	<0.01
Harlem Hospital			
September 1-12	37.9		
September 13-16*	55.5	+ 45.4%	<0.01
Metropolitan Hospital			
September 1-12	16.8		
September 13-16	37.0	+120.2%	<0.01
1965			
Bellevue Hospital			
September 1-24	12.1		
September 25-30*	35.7	+195.0%	<0.01
Harlem Hospital			
September 1-24	32.5		
September 25-30*	66.7	+105.2%	<0.01
Metropolitan Hospital			
September 1-24	16.6		
September 25-30*	47.2	+134.3%	<0.01

*Critical period.

APPENDIX

TABLE 9

ANNUAL ADMISSIONS, BRISBANE CHILDREN'S HOSPITAL[23]

Group	1955-1956	1956-1957	1957-1958	Total
Asthma	115	98	107	320
Asthmatic bronchitis	71	93	72	236
Total	186	191	179	556

TABLE 10

COMPARISON OF MOLD AND POLLEN COUNTS[63]
(Israel)

Town	Mold Count[a]	Pollen Count[b]	
	Monthly Mean per Plate	Monthly Mean per cm^2	Mean per cm^2
Arad	6.5-15.5	962	530
Beilinson	20.0-61.5	1,934	1,222

[a] 9 cm sediment plate exposed for 15 min.
[b] Durham gravity slide sampler.

TABLE 11

MAXIMUM DESITOMETRIC READINGS FOR COMPOUND A*[43]

Grains	Botanical Name	Readings Stem	Husk	Bran	Grain
Wheat	*Triticum vulgare*	58	94	86	12
Corn	*Zea mays*		88	85	14
Oats	*Avena sativa*	53	84	82	13
Barley	*Hordeum vulgare*	47	78	79	9
Rye	*Secale cereale*	15	22	10	4

Seed Group	Botanical Name	Readings Husk	Seed
Flax	*Linum usitatissum*	94	95
False Flax	*Camelina sativa*	93	94
Rape	*Brassica napus*	95	95
Turnip Rape	*Brassica rapa*	82	92

Pollen Group	Botanical Name	Readings
Short ragweed	*Ambrosia artemisiifolia*	96
Oak	*Quercus alba*	95
Cottonwood	*Populus trichocarpa*	92
Maple	*Acer saccharum*	87
Elm	*Ulmus americana*	63
Alfalfa	*Medicago sativa*	38

*A high reading represents a high relative concentration of Compound A.

TABLE 12

DERMAL AND BRONCHIAL REACTIVITY TO CANDIDA ALBICANS[59] (81 Patients)

No. of Patients	Immediate Skin Response	Delayed Skin Response	Immediate Bronchial Reaction Only	Immediate & Delayed Bronchial Reaction	Negative Bronchial Reaction
19	+	+	8	4	7
23	+	-	4	8	11
16	-	+	3	1	12
23	-	-	3	2	18
Total			18	15	48

TABLE 13

ABUNDANCE OF RAGWEEDS ACCORDING TO LAND USE CATEGORIES[98]

Land Use Category	Percent of Areas Represented in Each Abundance Scale Rating[a]				
	0	1	2	3	4
Cropland--corn	8.5%	50%	33%	8.5%	0%
Cropland--wheat	0	0	0	33	67
Cropland--oats	0	0	33	33	33
Alfalfa meadow	75	25	0	0	0
Pasture	81	0	9.5	0	9.5[b]
Grass Meadow	91	0	0	9	0
Parklands	90	10	0	0	0
Woods	100	0	0	0	0
Marshes	100	0	0	0	0
Roadsides	87	10	1	2	0
Residence property	100	0	0	0	0
Soybeans	0	50	50	0	0
Clover and clover mixtures	40	0	40	20	0
Timothy and timothy mixtures	100	0	0	0	0
One to three-year abandonment	0	44	14	28	14
Summer-fallowed fields	50	50	0	0	0

[a] Abundance Scale Rating:

0--No ragweeds observed.
1--Ragweeds present, but averaging less than 0.5 plants per square meter.
2--Ragweed density averaging from 0.5 to 1 plant per square meter.
3--Ragweed density averaging from 1 to 10 plants per square meter.
4--Ragweed density averaging over 10 plants per square meter.

[b] This value is based on observations of pastures used exclusively by swine at the time the study was made.

TABLE 14

COMMON ALLERGENIC PRODUCTS[52,64]

Product	
Pillows	Chicken, duck, and geese feathers, kapok
Stuffing in mattresses and toys	Kapok; cat, cattle, and horse hair
Rugs	Cattle and horse hair, wool
Fabrics	Goat, cattle, and horse hair; wool
Brushes	Cattle and horse hair, hog bristles
Furs	Sensitivities exist to indidual furs
Wigs	Human and horse hair
Cosmetics (wave set lotions, hair tonics, talcs, and perfumes)	Many contain orris root or flaxseed
Insecticides	Many contain pyrethrum derived from dried flowers of the chrysanthemum family, which is related to ragweed
Paints and varnishes	Flaxseed is used to produce linseed oil, an ingredient in many paints and varnishes
Fertilizer	Castor bean pomace

TABLE 15

POLLEN DISPERSAL[5]

Species (Means of Dispersion)	Horizontal Distances and Units Dispersed					
Agropyron cristatum (Wind)	Rods from field	5	15	25		
	Pollen grains	72	29	10		
A. intermedium (Wind)	Rods from field	5	12	25		
	Pollen grains	44	17	4		
Beta sp. (Wind)	Meters from seed fields	0	300	500	800	
	Pollen grains/cm^2					
Bromus sp. (Wind)	Rods from field	5	15	25	40	60
	Pollen grains	146	41	21	10	4
Cedrus atlantica (Wind)	Feet from source tree	40	120	240	325	700
	Pollen grains	189	116	71	51	0.1
C. libani (Wind)	Feet from source tree	15	75	135	195	
	Pollen grains	127	62	37	22	
Dactylis sp. (Wind)	Meters from field	0	200	400	600	800
	Pollen grains/cm^2	3,096	447	172	120	86
Fraxinus sp. (Wind)	Feet from source tree	25	50	150	400	
	Pollen grains	2,545	1,008	141	29	
Juglans regia (Air currents)	Feet from pollen source	60	150	500	1,000	1,600
	Pollen grains/mm^2/24 hr	4	2.8	1.4	0.6	0
Lolium sp. (Wind)	Meters from ryegrass field	0	200	500	700	900
	Pollen grains/cm^2					
Malus pumila (Wind)	Feet from source tree	0	165	330		
	Pollen grains	13	2	0.9		
Oryza sativa (Dehiscense and Wind)	Centimeters from pollen source	25	50	100	150	200
	Pollen grains	22	9	3	1	0.4

(continued)

TABLE 15 (Continued)

POLLEN DISPERSAL

Species (Means of Dispersion)	Horizontal Distances and Units Dispersed					
Panicum virgatum (Wind)	Rods from field	5	15	25	40	60
	Pollen grains	27	7	4	2	0.5
Parthenium argentatum (Wind)	Yards from guayule plants	100	400	850	1,200	
	Pollen grains/in^2					
Penniselum glaucum (Wind)	Yards from release point	4	50	200	400	
	Pollen, percent	100.0	8.9	0.8	0.4	
Phleum pralense (Wind)	Meters from timothy field	0	100	200	300	500
	Pollen grains/cm^2					
Picea sp. (Wind)	Feet from source tree	0	165	330		
	Pollen grains	9.7	0.1	0.7		
P. cembroides (Wind)	Feet from source tree	10	75	150	225	300
	Pollen grains	8,479	462	86	38	52
Populus sp. (Wind)	Feet from source tree	50	500	1,400	3,200	4,200
	Pollen grains	107	86	76	69	66
P. deltoides	Feet from source tree	25	250	500	1,550	3,550
	Pollen grains	115	62	46	20	0.3
Secale cereale (Wind)	Rods from rye field	5	15	25	40	60
	Pollen grains	453	232	124	52	11
	Meters from rye field	100	300	500	700	
	Pollen grains/cm^2	4,181	2,579	1,834	1,343	
Ulmus sp. (Wind)	Feet from source tree	500	1,100	2,700	5,500	
	Pollen grains	115	152	12	8	
Zea mays (Wind)	Rods from field	5	15	25	40	60
	Pollen grains	18	6	3	2	0.8
	Feet from pollen source	10	30	50	70	
	Pollen grains	7,330	341	121	30	

TABLE 16

POLLEN COUNTS, ST. LOUIS SITE, 1963-1964[36]
(In Grains per Cubic Yard*)

	Average Count Per Month									
Month Year	Elm Hackberry	Poplar Cottonwood	Maple	Oak	Sycamore	Hickory Walnut	Grass	Plantain	Goosefoot	Ragweed
March 1963	134.9	30.5	4.9	17.5	4.2	2.5	0	0	0	0
1964	40.4	0	1.1	0	0	0	0	0	0	0
April 1963	1.7	7.5	0.4	254.3	92.1	13.4	0.2	0	0	0
1964	12.8	10.0	2.1	117.2	78.6	3.3	0	0	0	0
May 1963	0.2	0	0	6.2	0.3	12.3	5.0	0	0	0
1964	0.9	1.4	0	78.2	9.4	39.3	4.6	0	0	0
June 1963	0	0	0	0	0	0.3	7.6	1.2	0	0.2
1964	0	0		0	4.4	0.2	4.3	2.8	0.5	0.2
July 1963	0	0	0	0	0	0	2.8	1.9	0.7	1.0
	0	0	0	0	0	0	0.8	1.3	0.9	0.8
Aug. 1963	0	0	0	0	0	0	0	1.6	21.9	86.4
1964	0	0	0	0	0	0	0	0	11.2	47.8
Sept. 1963	0	0	0	0	0	0	0	0	31.4	112.7
	0	0	0	0	0	0	0	0	30.7	144.3

*Multiply by 1.3 = grains per cubic meter.

TABLE 17

NUMBER OF ALTERNARIA SPORES PER CUBIC FOOT[81]

Time	Number per Cubic Foot
5 a.m.	12
6 a.m.	7
7 a.m.	9
9 a.m.	13
11 a.m.	16
1 p.m.	17
2 p.m.	13
5 p.m.	16
6 p.m.	19

TABLE 18

RECOMMENDED CONDITIONS FOR USE OF COMMON GERMICIDAL SUBSTANCES (AT ROOM TEMPERATURE, 25°C)[62] FOR FUNGI

Germicide	Concentration	Exposure Time
Phenol	5%	15 min
Lysol	3%	15 min
Hypochlorite + 1% wetting agent (Naccanol, etc.)	2,000 ppm	10 min
Caustic sodium hydroxide	10%	30 min
Formalin (37% HCHO)	5% solution	10 min
Steam formaldehyde vapor in closed area	1 ml/ft^3 in air with Rh* above 80%	30 min
-Propiolactone	200 mg/ft^3 in air with Rh* above 80%	30 min
Ethylene oxide gas	300 mg/liter	8-16 hr

*Rh = relative humidity.

TABLE 19

RESOURCE COSTS OF DISEASES ASSOCIATED WITH AIR POLLUTION[57]

Basis of Cost	Annual Costs Associated With Selected Diseases,* Millions of Dollars						
	Cancer of the Respiratory System	Chronic Bronchitis	Acute Bronchitis	Common Cold	Pneumonia	Emphysema	Asthma
Premature death	518	18	6		329	62	59
Premature burial	15	0.7	0.2		13	2	2
Treatment	35	89		200	73		138
Absenteeism	112	52		131	75		60

*Using a discount rate of 5 percent.

TABLE 20

ASTHMA-HAY FEVER PURCHASED ACQUISITION OF PRESCRIBED MEDICINE, JULY 1964-JUNE 1954[3]

Number of conditions	14,375,000
Percent of total prescribed medicine acquisitions	2.7%
Number of purchased acquisitions of prescribed medicine	21,194,000
Percent of total number purchased acquisitions of prescribed medicine:	
Cost under $2.00	26.0%
2.00-2.99	25.2%
3.00-4.99	33.4%
5.00-6.99	9.3%
7.00	
Average cost per purchase of prescribed medicine	$3.30

TABLE 21

SIX MOST FREQUENT CAUSES OF NON-MAJOR ACTIVITY LIMITATION, JULY 1963-JUNE 1965[25]

Cause	Percent of Total
Arthritis and rheumatism	11.9
Heart condition	10.7
Impairment of back or spine	7.7
Mental and nervous conditions	7.0
Asthma-hay fever	6.8
Impairment of lower extremities and hip	6.3

TABLE 22

AVERAGE NUMBER OF PERSONS REPORTED AS LIMITED IN ACTIVITY DUE TO SELECTED CHRONIC CONDITIONS, JULY 1961-JUNE 1963[115]

	Usual Activity Status (Average Number of Persons with Conditions X 1,000)				
Cause of Limitation	All Activities	Usually Working	Keeping House	Retired	(Age: 17+ yrs)
All conditions	22,275	6,384	7,525	4,668	2,257
Asthma-hay fever	1,118	242	281	190	117

TABLE 23

DEATH RATE (1950 TO 1966) AND DEATHS (1965 AND 1966) FROM SELECTED CAUSES[105]

	Deaths per 100,000 Population						Deaths	
Cause	1950	1955	1960	1964	1965	1966	1965	1966
All Causes	963.8	930.4	954.7	939.6	943.2	951.3	1,828,136	1,863,149
Tuberculosis (all forms)	22.5	9.1	6.1	4.3	4.1	3.9	7,934	7,625
Meningococcal infection	0.6	0.6	0.4	0.4	0.5	0.4	850	876
Asthma	2.9	3.6	3.0	2.3	2.3	2.2	4,520	4,324
Influenza and pneumonia (except pneumonia of newborn)	31.3	27.1	37.3	31.1	31.9	32.5	61,903	63,615
Influenza	4.4	1.7	4.4	0.9	1.2	1.4	2,295	2,830
Pneumonia	26.9	25.4	32.9	30.2	30.8	31.0	59,608	60,785
Bronchitis	2.0	1.9	2.4	2.8	3.0	3.1	5,772	6,151